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Welcome

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Custom PC Issue 159

Editorial EDITOR
Ben Hardwidge
editor@custompcmag.org.uk

MODDING EDITOR
Antony Leather

GAMES EDITOR
Rick Lane

ART EDITOR
Bill Bagnall
www.billbagnalldesign.com

PRODUCTION EDITOR
Julie Birrell

CONTRIBUTORS
Edward Chester, Gareth Halfacree,
James Gorbould, Mike Jennings,
Paul Goodhead, Richard Swinburne,
Simon Treadaway, Tracy King

PHOTOGRAPHY
Antony Leather, Gareth Halfacree,
Mike Jennings

Publishing & Marketing PUBLISHER
Simon Brew
simonbrew@hotmail.com

LICENSING MANAGER
Carlotta Serantoni
Carlotta_Serantoni@dennis.co.uk
+44 (0)20 7907 6550

LICENSING & SYNDICATION ASSISTANT
Nicole Adams
Nicole_Adams@dennis.co.uk
+44 (0)20 7907 6134

SYNDICATION SENIOR MANAGER
Anjum Dosaj
+44 (0)20 7907 6132

Commercial & Advertising
Charlotte Milligan
charlotte_milligan@dennis.co.uk

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Dennis Publishing Limited
Tel: 020 7907 6000 fax 020 7907 6193

DIRECTOR OF ADVERTISING
Julian Lloyd Evans

MANAGING DIRECTOR DENNIS TECHNOLOGY
John Garewal

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NEWSTRIDE DIRECTOR
David Barker

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Brett Reynolds

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Ian Leggett

CHIEF EXECUTIVE
James Tye

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40 Graphics wars

Nvidia's Titan X might generate covetous excitement, but only a handful of gamers can afford to pay the ludicrous sum of money it demands. For most of us, the GPU sweet spot is the sub-£250 sector, and the battleground here is really hotting up. Not only has AMD released several new GPUs in this price league, but Nvidia has also brought its Pascal architecture into play with its GeForce GTX 1060 6GB and 3GB cards.

This month we take a look at all the new sub-£250 options, with various memory configurations, to see what you need to find out which cards offer the best bang per buck in games at 1,920 x 1,080 and 2,560 x 1,440. Along the way, we also analyse how much graphics memory you really need, and take a look at what's on offer if you drop right down to the £100 mark too.

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P40

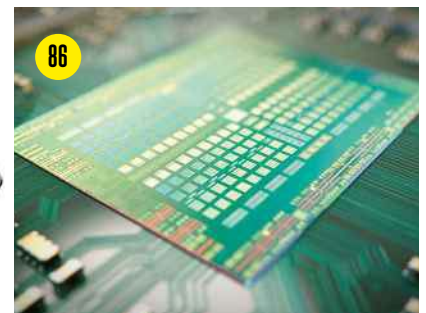


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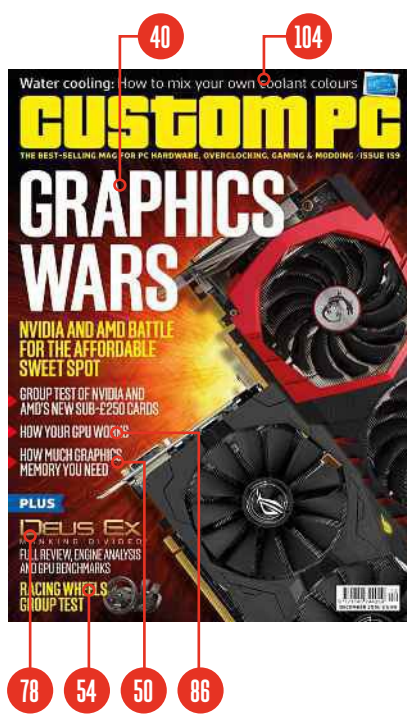
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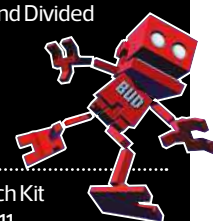
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BEN HARDWIDGE / FROM THE EDITOR

GRAPHICAL EQUATIONS

Ben Hardwidge discusses the benefits of using maths to work out GPU review scores, and eats (some of) his words about graphics memory

There's nothing quite like maths for turning our human comprehension into cold, hard numbers. There's nothing romantic about our graphics card scoring Excel spreadsheet, but it does a grand job of removing our preconceptions and prejudices, just telling us which cards offer the best bang per buck in raw, unpretentious numbers.

We started using this scoring system a few years ago, to shift the focus onto useful, real gaming performance. For example, we wanted to avoid rewarding cards for getting 15fps in a game, over a card that gets 10fps, when both results were ultimately unplayable.

You can find out more information about the scoring system in our graphics card Labs test on p41, but I wanted to use this space to discuss the results, because sometimes an Excel spreadsheet can turn up some surprises – results you're simply not expecting. In our Issue 140 graphics card Labs, for example, the spreadsheet turned all our preconceptions on their heads by telling us that AMD's ageing Radeon R9 290 cards offered the best bang per buck. We even accounted for efficiency in this test, and the R9 290 and 290X still won out over Nvidia's Maxwell cards. That came as a shock – we were expecting an easy win for the GTX 970 in that test, but the maths told another story – thanks to AMD's aggressive price cuts, its older cards were more competitive.

We've had some surprises in this month's sub-£250 graphics card Labs test too. Polaris has been AMD's big comeback architecture, representing the company's new priority of focusing on precisely this market first. We were expecting the

Radeon RX470 to win out at the budget end, with a tough battle between the Radeon RX480 and GTX 1060 6GB at the upper end, particularly as this month sees us adding an AMD Gaming Evolved title, Deus Ex: Mankind Divided, to our test suite.

But the maths told us otherwise. Both the RX470 and RX480 are still good GPUs – there's no problem there. Again, it's the pricing – the bang per buck – that lets them down. The GeForce GTX 1060 3GB just annihilates everything in its path in this price league. You can pick up a card for just £185 inc VAT, and it offers amazing frame rates in most games, despite having just 3GB of memory.

This brings me onto my next point, which is that, last month, I wrote a column ranting about graphics card memory, and how you don't need 12GB of memory on a Titan X, nor more than 4GB of memory on a mid-range card. A few of you wrote to me, some heartily agreeing with me, and others disagreeing with me, pointing to examples where I was wrong.

I like to think that I'm someone who is prepared to change their mind in the light of new evidence, so I decided to run some tests to monitor VRAM use for this month's Labs test. You can see the results on p50, and yes, once you start testing some games at Ultra settings, you do indeed go beyond the 4GB VRAM barrier, and in some cases at playable frame rates on mid-range cards too. On this level, I concede that I was wrong. That said, though, you really have to push a 3GB or 4GB right to its limit on a very demanding game to see a drop in performance. For the most part, a 3GB GTX 1060 card will do the job fine. **GPC**

Our spreadsheet tells us which cards offer the best value in raw, unpretentious numbers

Ben Hardwidge is the editor of Custom PC. He likes PCs, heavy metal, real ale and Warhammer 40,000. editor@custompcmag.org.uk [@custompcmag](https://twitter.com/custompcmag)



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RICHARD SWINBURNE / VIEW FROM TAIWAN

IN SEARCH OF SILENCE

Richard Swinburne attempts to build a high-performance PC with no whirring fans, cooler pumps or hard disks

Silent PCs often use low-power chips, forgo graphics cards and are housed in exotic cases with heatpipes everywhere. Meh! These approaches are unsatisfactory for my needs. I want performance, I want to game and I want my PC to be as normal as possible, but I also want literal silence, not the marketing box claims of 'silence' that so often fail to live up to expectations.

So, over the past several months, I've been attempting to build a fanless PC with off-the-shelf hardware, while maintaining as much performance as possible. Ultimately, I've had to compromise by going semi-fanless, but I've still tamed a Core i7-5960X CPU, along with an Nvidia GeForce GTX graphics card, in a machine that makes zero noise when it matters. And when I say 'zero noise', I mean it – there are no fans spinning, no pumps whirring and no spinning disks. The entire system is static. How?

Firstly, I removed all the internal case fans. My hardware might run hotter, but if it's still stable then so what? My ambient air temperatures have been over 30°C during Taipei's steamy summer months, but my machine remains stable, so I'm sure others can do the same. Next I moved all my storage hard drives to my NAS box in another room and went with a single M.2 NVMe SSD in the PC. A 256GB drive was enough for my needs, but M.2 drives are now available in 1TB capacities too (see p20).

I also bought a fanless power supply. It was a big expense, but worth it since PSUs last several upgrades. My previous Seasonic X-650W lasted for seven years, so in a moment of brand loyalty, I went for Seasonic again with a fanless SS-520FL PSU. It's super-

efficient, 80 Plus Platinum rated and I'm confident that its 520W rating will offer enough power for my present and future needs. The PC industry is focusing on ever more efficient hardware rather than raw power at all costs, so I'm sure I'll be fine.

My all-in-one liquid cooler was gurgling after three years of use, so I dumped it. It had a tiny, whiny pump anyway. Instead, I bought a Thermalright Le Grand Macho – a mega heatsink with seven heatpipes, which needed to match a chassis with an air vent in the roof above the CPU socket to allow convection. A Fractal Define S would be perfect, but the In Win 805 I already owned would also be fine.

With the system built, I tested the 5960X with a sustained all-core load from video encoding. The Macho did its best, but I found I still needed a system fan in the rear of the chassis. My Asus Rampage V Extreme motherboard (like other recent Asus boards) has a fan-stop option in its fan control software, so I set it to turn off the fan at temperatures below 45°C, so it's never running

when I'm watching video, listening to music, writing or web browsing. Similarly, some graphics cards offer fan-stop technology under a set temperature; until very recently, I used a Galax GTX 960 EX OC, which had fan-stop technology.

I've basically achieved total silence, as long as I'm not gaming, and I wear headphones then anyway. My main mistake for gaming was buying a Galax 1070 EX card that turned out not to have fan-stop technology. Argh! Why remove the feature? You can learn from my mistake though. Both MSI and Asus even offer high-end GTX 1070, 1080 and AMD RX cards with fan-stop technology to reach that fanless-as-possible goal. **CPC**

I also want literal silence, not the marketing box claims of 'silence'

Richard has worked in tech for over a decade, as a UK journalist, on Asus' ROG team and now as an industry analyst based in Taiwan @Bindibadgi



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TRACY KING / SCEPTICAL ANALYSIS

NO, PC GAMERS AREN'T LIKE RACISTS

Tracy King debunks Michael Pachter's latest comments in the press

Sticks and stones may break my bones, but words will never hurt me ... hang on, someone called us, what? Racists?! Michael Pachter, well-known gaming industry analyst and pundit, has inflamed and enraged the Internet by telling the Daily Star, 'I think PC gamers are like racists; they only like their own kind and they have no interest in venturing out and mixing with other races. PC gamers are arrogant twits who are convinced what they do is better than what anybody else can possibly do.'

Yikes. It's an inflammatory thing to say, although perhaps not for the reasons that are most common in angry responses. It's inflammatory because it trivialises actual racism, an issue which everyone may have noticed is particularly sensitive at the moment. We may really, really like PCs. We may live for gaming. We may even adamantly insist that PCs are the superior gaming platform (which for certain values of 'superior' is absolutely the case). We don't, as far as I've noticed, actively discriminate against console gamers in, say, the job market. We don't shoot Mac users. We don't have a history of oppressing with violence anyone who doesn't conform to our PC gaming preferences. Pachter said a silly, thoughtless thing and he should apologise to those affected by racism.

But of course, internet tensions being what they are, lots of people are angry on behalf of PC gaming sentiment rather than because racism really doesn't need to be compared to a gaming platform preference. The issue is compounded by the 'PC Master Race' meme, which started as an obvious satire by Ben 'Yahtzee' Croshaw but has now become a subculture identifier (most people know that 'master race' is a Nazi term and understood that Croshaw was mocking PC gamer

enthusiasm, but the name was re-appropriated as a way of insulting other gamers). It's unfortunate that this particular meme has caught on because, to outsiders, it does invoke actual racism, and it's complicated to explain The Escapist to non-gamers. But that's the point of memes. They're in-jokes (albeit on a large scale). PC Master Race is funny to those inside the joke precisely because gaming is a hobby and ultimately trivial; it's nothing whatsoever like Nazism.

While you can't put the genie back in the bottle, the PC Master Race meme, like all others, will go away by itself over time as the current generation ages out of the subculture.

However, the substance of what Pachter said, which is that many PC gamers don't have any interest in 'venturing out' and 'mixing with' other types of gamers is in many cases true, for one very good reason. Hardware compatibility. How can you play with console gamers when that facility doesn't exist (or where it's been beset by problems when it has existed). Why

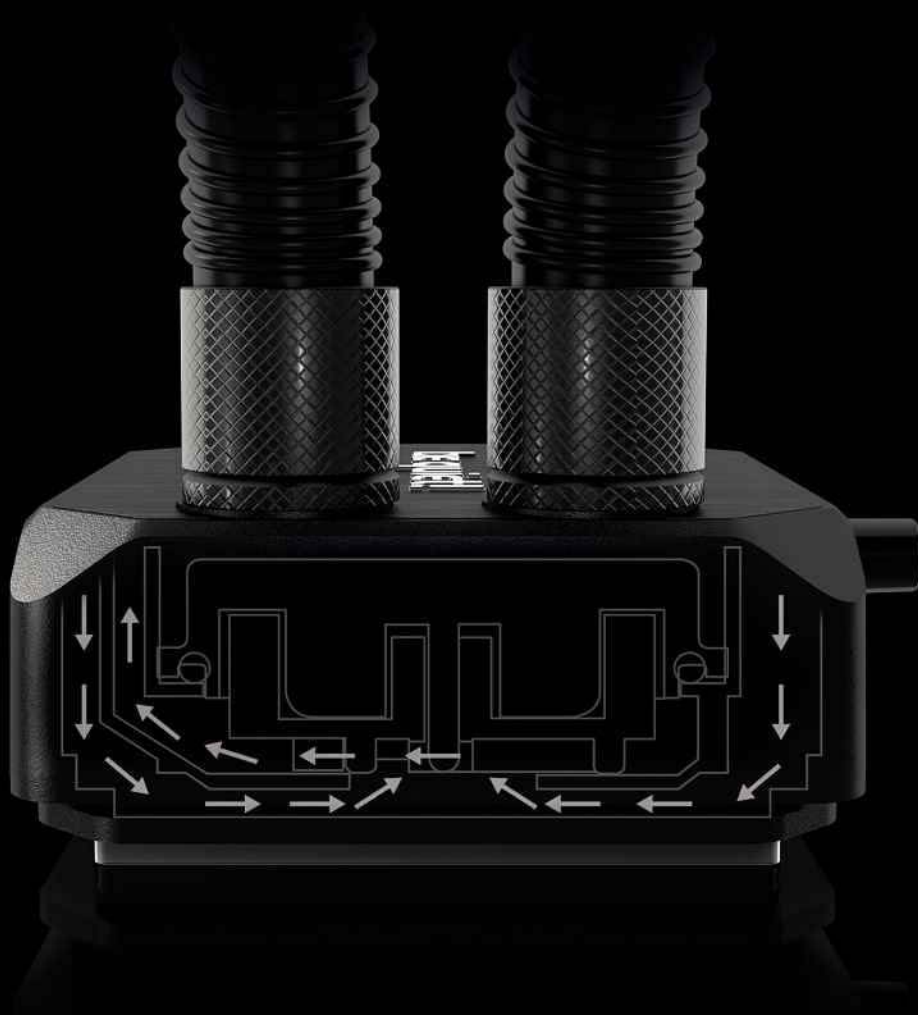
would you buy a console when you've already invested in PC games? What Pachter failed to mention was that this works the other way around too. For example, Tekken project lead Katsuhiro Harada recently tweeted that console gamers perceive PC gamers as 'cheaters'.

The biggest contributing factor to the demise or confirmation of the attitude that the PC is indeed the superior platform will be cross-platform play. Where cross-platform play does exist, such as in Rocket League, PCs have had the edge, so there's a lot of work to be done to create a level playing field, eliminating the benefits of keyboard and mouse. But cross-platform play will ultimately bring PC and console players together, and then we'll really see who's the master. **GPC**

Gaming is a hobby
and ultimately trivial;
it's nothing like Nazism

Gamer and science enthusiast Tracy King dissects the evidence and statistics behind popular media stories surrounding tech and gaming [@tkingdoll](#)

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We take a look at the latest newly announced products

Corsair reflects

Corsair has unveiled an exclusive line of 3200MHz enthusiast memory with chrome mirror-finish heatsinks. Just 1,000 of the new Dominator Platinum Special Edition kits will be released, encompassing 500 32GB (4 x 8GB) kits and 500 32GB (2 x 16GB) kits. In addition to the shiny chrome finish, the kits will also be available in a black anodised finish. According to Corsair, all the modules are carefully screened and can be safely overclocked to 3600MHz. The modules also feature a white LED pipe, a ten-layer PCB and 3200MHz timings of 14-16-16-36. The kits are available now from www.corsair.com for £280 inc VAT.



First glimpse of AM4 socket

The first photo of AMD's new AM4 CPU socket has been leaked online to tech site www.hwsn.hu, showing a monstrous socket that's packed full of holes for AMD's forthcoming Zen CPUs. Unlike Intel, which has been using a land grid array (LGA) socket since the end of the NetBurst era, AMD is sticking with a traditional pin grid array (PGA) socket design, with the pins all on the CPU.

The new AM4 socket is significantly bigger than its AM3 predecessors, though, featuring 1,331 pin holes, compared to just 942 pins on a Socket AM3+ CPU. The size of the socket also means that new cooler mounts will be needed for the CPU.

EVGA lights up PSUs

Not wanting to miss out on the latest trend for putting LEDs into every component possible, EVGA has just announced a new range of LED-equipped power supplies. The new SuperNOVA G2L PSUs feature white LEDs in the modular cable connectors, and also sport 80 Plus Gold certification and zero fan movement at low to medium loads. Both 750W and 850W versions will be available, with the latter now available from www.scan.co.uk for £135 inc VAT.



Valve releases Steam accessories

Following up on the release of the Steam controller, as well as Steam OS, nearly a year ago, Valve has now released a range of accessories for the controller, including a variety of skins for both the controller and the Steam Link box. In addition, Valve is also offering a wireless receiver for the controller, a battery door that gives you space for the wireless receiver and a Steam controller carry case. The accessories are all available now from <http://store.steampowered.com/sale/accessorysalepage>



NZXT updates S340 case for VR

NZXT has updated its classic budget S340 case with a new Elite version, which adds a tempered glass side panel and a host of features for VR headsets, including front-mounted HDMI USB ports for easy connection, plus a cable management puck, which enables you to wind your cables and hang up your headset.

In addition, NZXT has added an extra SSD tray to the design over the original S340, as well as a new cable clamping system. The NZXT S340 Elite is available from www.overclockers.co.uk now for £89 inc VAT.

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Letters

Please send us your feedback and correspondence to
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When you need more VRAM

I was reading your article in Issue 158, and thought that perhaps it was a little overzealous to say people don't need 8GB or 12GB over 4GB graphics cards? I say this because I recently used over 6GB playing Shadow of Mordor, and almost 8GB playing Black Ops 3 (both on Ultra settings) running at 1,920 x 1,200, let alone 4K. The fact that I almost maxed out my GTX 1080's memory is a surefire way to tell that more VRAM is needed in order to allow for rendering overheads.

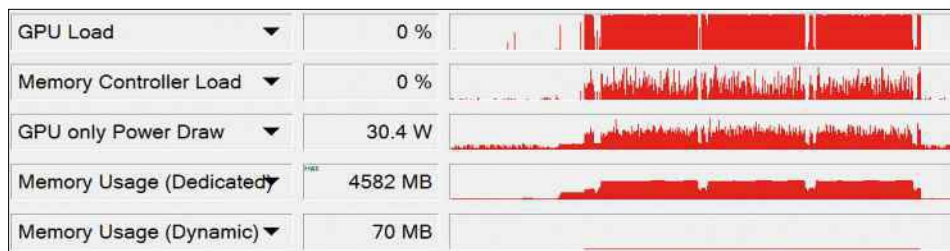
Yes, GPUs are overpriced, especially the most recent generation, but to say that people don't need more than 4GB on a graphics card because the VRAM won't get used in the card's lifespan is quite an exaggeration, and not entirely accurate.

ANDY DAVIES

Ben: A few people have written to me about this, some agreeing with my stance, and others disagreeing, so I decided to run some tests.

You can see the results on p50, and while I haven't tested Black Ops 3 or Shadow of Mordor, I've still had to concede that some games do indeed push beyond 4GB of graphics memory, even at 1080p, if you run at Ultra settings. I've discussed this in my column on p8, but to a certain extent, I've had to stick some of the words from last month's column into a casserole this month.

However, I still think there's some truth in the gist of my original column, even if the margins are much tighter than I thought. You often see very low-end cards with more memory than they can possibly use, for example. Also, you're using a GTX 1080 8GB, which can clearly handle those games at Ultra settings, but there are lower-spec



Peak VRAM usage went over 4GB in our recent tests in Deus Ex: Mankind Divided

cards that wouldn't be able to run the game at those settings, no matter how much memory they have.

For example, a GTX 1080 8GB could probably play Deus Ex: Mankind Divided at 2,560 x 1,440 with Ultra settings, but neither a Radeon RX480 4GB, nor a RX480 8GB card, can do the same, despite the latter having the same amount of memory.

The extra memory is only useful if your GPU has enough power to deal with those settings in the first place, and that often isn't the case at the lower end of the scale.



Try some different graphics card manufacturers

While I'm a fan of your reviews, I feel like your choice of third-party graphics cards is lacking. In each of the last three issues (September, October and November) we've seen Asus models of the GeForce GTX 1070, GTX 1060 6GB and AMD Radeon RX470 respectively.

Don't get me wrong, I'm a big fan of Asus graphics cards. However, and I understand you probably have a good working relationship with Asus, it would be nice to see some

cards from other manufacturers, such as EVGA or Gigabyte, to give just two examples. Given the slew of recent graphics card releases, it

seems a shame to just review Asus' third-party designs.

DOMINIC MOASS

Ben: I completely hear you, Dominic. The problem we've found is that, at launch, not many third-party card manufacturers have reviews samples they can send to us. We invited both Sapphire and EVGA, among others, to send us samples for the reviews you mention, for example, but they weren't able to come up with the goods, so we ended up falling back on Asus. However, while this month's Labs concentrates on GPUs rather than third-party cards, we did manage to get samples from Gigabyte, Zotac and MSI, as well as Asus – hopefully, we'll be able to get a wider variety of samples in for review in the future.



GPU water cooling

I know there are a lot of PC users that bang on about the latest processors and their potential overclocking speeds, but for running normal desktop applications or games, processor clock speed isn't that important. I'd be interested to see the assembly and overclock of a water-cooled graphic card, so I can see what considerations there are regarding the waterblock, tubing, radiators, coolant, fan, case suitability, maintenance and so on. I'd also like a detailed explanation of all the parameters that can be adjusted.

JOHN ERDELYI

Asus' GeForce GTX 1070 Strix card



For running normal desktop applications or games, processor clock speed isn't that important

Ben: We've looked at water-cooling graphics cards a few times over the years, but not in a huge amount of depth. I'll put it on the list for potential future articles.



Waterless engine coolant

I'm spec'ing up my 'ultimate' workhorse PC, and I'm thinking about liquid cooling. Having another interest in the custom car world, we sometimes use waterless engine coolant (Google that phrase to see what I mean), and I have some to hand with which I could fill a PC cooling system. In a car, it has the advantage of protecting against rust in any place where the cooling system is in contact with steel. It also doesn't freeze under normal temperature extremes, it doesn't boil and it reduces the risk of over-pressurising the system.

In a PC, I'd expect it to have advantages over water. If the circulation pump fails, it will withstand a much higher temperature in the CPU block before boiling (if at all), and therefore not risking a rupture.

As it's not water-based, it will also have no problems with corrosion or short circuits if any leaks.

What's more it's not prone to fungal growth or sludging up, so it won't ever need replacing.

The only alternatives to plain water I've found for PC cooling seem



to be water-based liquids with various additives (including coloured dyes that don't interest me), meaning they require periodic flushing and replacement, much like conventional engine coolant. What are your thoughts?

KEN WOOD

Ben: You're certainly not the first person to think of this idea Ken, don't worry.

This isn't something I've tried myself, but I know a few people in the industry who have tried using waterless engine coolant for PC water cooling, and they've reported seeing very high temperatures compared with distilled water.

Part of the problem is that engines have large parts where the heat is spread out, while a PC component is

Waterless coolant might be fine for cooling engines, but it can't beat good old-fashioned distilled water for PC water cooling

very small and has an awful lot of heat concentrated in one area – it relies on the liquid being pushed quickly over the chip and the liquid being thermally conductive enough to move as much of the heat as possible.

Basically, the chemical combination that makes up waterless engine coolant doesn't conduct heat as well as distilled water. It may well work fine as an engine coolant, but it's hard to beat distilled water for basic thermal conduction, which is the key factor for PC water cooling.

All of which is a shame, as it would be great to have a water-cooling coolant that didn't need flushing out and replacing now and then, but if you want good PC cooling, that's currently the best way to do it if you're using liquid cooling. **GPC**



Twitter highlights

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jamesfreeman510 I'm pretty sure you've seen many custom PCs. But have you ever seen a Lego head custom PC?

Ben: Nope, I haven't, but what a great idea!

Chadders78 Excellent bit on graphics memory. Been saying the same thing

for ages. I have the same thoughts on Core i7 chips and SLI/CrossFire.

Ben: Thank you, although I've had to revise my position a little on p50 this month!

PCenthusiastUK Finally reached a milestone of 10,000,000 @foldingathome points. Would like to run on more efficient H/W.



EckhardMahne Got myself a Samsung Evo

500GB SSD. Following @CustomPCMag mag recommendations as always.

ImCinderz relaxing day off. Quick #vape and #beverageapproved



kiddser A bit late in noticing, but congrats to DocJonz for finally overtaking me in @CustomPCMag @foldingathome Team. #tookvertime #I'llbeback =]

WHEN'S THE NEXT MAG COMING OUT?

Issue 160 of **Custom PC** will be on sale on Thursday, 10 November, with subscribers receiving it a few days beforehand.



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Reviews

Our in-depth analysis of the latest PC hardware



Reviewed this month

Cooler Master MasterPulse Over-Ear p19 / Samsung SSD 960 Pro and 960 Evo preview p20 /
Asus Rampage V Edition 10 p22 / DeepCool Genome II p24 / Thermaltake Core G3 p26 /
Scan 3XSLG17 Carbon Extreme p30 / BenQ Zowie XL2730 p32 / Custom kit p34

GAMING HEADSET

Cooler Master MasterPulse
Over-Ear / **£60** inc VATSUPPLIER www.box.co.uk / MODEL NUMBER SGH-4700-KKTA1

With HyperX's fantastic Cloud headset still doing the rounds for around £60, launching a new headset in a similar price league will certainly be a challenge, but Cooler Master is in with a good chance, with numerous good examples of headsets to its name. The latest model is the MasterPulse Over-Ear; as its name suggests, it uses circumaural earcups. It retails for dead on £60, so it has plenty of competition, including the aforementioned HyperX Cloud, but it makes a good impression out of the box.

It feels solid, with a tough aluminium frame stretching around the rim with an expandable headband. The aluminium frame splits just before it reaches the earcups, doing a good job of limiting vibrations from accidental knocks.

The earcups can adjust vertically but not horizontally, although this design decision doesn't impact on comfort. The earcups lack the ability to rotate for easy transportation and storage though. Also, while the earcups sport large padded cushions, they don't offer quite enough cushioning to raise your ears away from the hard plastic coating

inside. Thankfully, the plastic is barely noticeable and doesn't significantly affect comfort, even after a few hours of use.

The headband is well-padded too and there was only a hint of head strain after a few hours of use. The MasterPulse Over-Ear will have trouble fitting around larger heads, though, with only minimal adjustment in the headband.

In terms of audio setup, there's no USB sound card integrated into the MasterPulse – just 3.5mm mini-jacks. There's a 1.3m cable attached to the headset with a four-pole mini jack, and a second cable adding another 30cm or so, splitting into headphone and microphone mini-jacks for PC use. Strangely for a gaming headset, there's no external microphone, but you still get one courtesy of a small hole in the left ear cup, along with a mute button on the inline volume control.

The MasterPulse Over-Ear's main audio feature is called Bass FX – the earcups are closed out of the box, but magnetic removable caps enable you to alter the bass by opening up the ear cups. This feature is meant to enrich the bass tones, and there's definitely a discernible effect when you enable it, with the bass becoming slightly punchier and deeper as if it had been boosted in an equaliser. Opening the ear cups in this way does also allow a little more sound to escape though.

Sound quality is good, if a little bass-heavy, especially when you remove the ear cup caps, which also makes the sound a little muddy in the



mid-range. However, the MasterPulse coped well in a range of situations, including a variety of music styles and games, with plenty of detail even at the high end. Despite the microphone lacking the physical presence of other headsets, it did a fairly good job at recording voice too – good news if you like the idea of ditching the microphone boom.

Conclusion

The MasterPulse's Bass FX feature is a little gimmicky, but it does make a difference if you like your audio bassy. Meanwhile, comfort is good and sound quality is well-rounded, although this headset isn't recommended if you have a larger than average head. The main problem for the MasterPulse, of course, is that it's up against the similarly priced HyperX Cloud, which still has the edge in terms of sound quality and design. However, the MasterPulse Over-Ear still offers decent sound quality, and remains worth considering if you find boom microphones distracting and like plenty of bass.

ANTONY LEATHER

/SPECIFICATIONS

Cup type Circumaural
Connection 3.5mm jacks
Drivers 44mm
Frequency response 20Hz-20KHz
Impedance 50 Ohms

SOUND
33/40

DESIGN
26/30

VALUE
24/30

OVERALL SCORE
83%

VERDICT

A well-rounded headset with a built-in microphone, good bass reproduction and a reasonable price, although it's up against stiff competition.

Samsung SSD 960 Pro and 960 Evo

Samsung created a splash last year with its 950 Pro SSDs. Using the latest NVMe protocol over PCI-E 3, they brought unprecedented performance for the money. Thanks to the tiny M.2 form factor, they could also bring that performance to desktops and laptops alike. A year later, the 950 Pro range still reigns supreme, but Samsung hasn't rested on its laurels – it's just announced a new line of high-performance NVMe M.2 SSDs – the 960 Pro and 960 Evo, boasting sequential read speeds that are up to 1,000MB/sec faster than those of the 950 Pro drives.

Samsung 960 Pro

The flagship Pro model now comes in capacities up to 2TB, marking a four-fold increase over the maximum capacity of the 950 Pro range. There will also be 512GB and 1TB models available, so the entry-level capacity for the Pro range is now doubled. However, as a result, the lowest price you'll be able to pay for a 960 Pro drive is \$369 US (UK pricing hasn't been revealed yet), which is some \$169 more than previously. This price rises to \$629 for the 1TB version and a whopping \$1,299 for the 2TB drive.

Nonetheless, for that extra cash you get a big leap in performance. Sequential read and write speeds are rated at 3,500MB/sec and 2,100MB/sec respectively for the 2TB version, which is 1,000MB/sec and 600MB/sec faster than the maximum speeds of the 950 Pro range. Meanwhile, random IOPs have also jumped from 300K to 440K (read) and from 110K to 360K (write).

What you don't get, though, is the longevity of the older drives. While the 950 Pro had a class-leading ten-year warranty, the 960 Pro's warranty drops to just five years, which is quite disappointing for the price of these drives. That said, overall endurance hasn't dropped. Samsung still claims a maximum terabytes written (TBW) of 400TB, 800TB and 1.2PB (petabytes) for the three capacities. It's just that you won't be covered if you experience an unexpected failure after five years.

Samsung 960 Evo

The 960 Evo range replaces the 850 Evo M.2 series, which was limited to using the slower SATA interface despite its M.2 form factor. As such, it's less of a surprise to see large gains in performance for the 960 Evo as it moves to a PCI-E interface, but the numbers are impressive nonetheless.

Where the 850 Evo was limited to 540MB/sec read and 500MB/sec write speeds, the 960 Evo leaps to 3,200MB/sec and 1,900MB/sec for the largest drive and only drops to a 1,500MB/sec write for the smallest drive. Random IOPS have also increased from the 850 Evo's 97K (read) and 89K (write) to 380K (read) and 360K (write) on the 960 Evo.

Again, these gains don't come for free. While the 256GB 850 Evo M.2 is currently available for around \$95 US, the new equivalent 960 Evo is set to cost \$130. Meanwhile, the 512GB and 1TB versions are set to cost \$249 and \$479.

That potentially makes the 512GB version a sweet spot for enthusiasts looking to make a big leap in performance and capacity from an older 128GB or 256GB drive – you'll effectively be getting the performance of last year's flagship 950 Pro for about \$100 less.

On the downside, there's only three years of warranty cover, although the endurance is still pretty solid; maximum TBW has increased from 150TBW to 400TBW over the 850 Evo M.2 drives.

Technological advancements

Both the 960 Pro and Evo are based on Samsung's current 48-layer V-NAND tech, which stacks 48 layers per die, with each package consisting of up to 16 256Gb dies stacked on top of each other for a total of 512GB per package. The Pro series uses four packages while the Evo line has just two, hence the difference in capacities.

The big difference between the Pro and Evo drives, though, is that the Pro uses 2-bit (MLC) NAND while the Evo uses 3-bit (TLC) NAND. This means that, as well as greater longevity, the Pro can maintain its claimed write

COMPARATIVE SPECS

	SAMSUNG SSD 960 PRO 2TB	SAMSUNG SSD 960 PRO 1TB	SAMSUNG SSD 960 PRO 512GB	SAMSUNG SSD 960 EVO 1TB	
Form factor	Single-sided M.2 2280	Single-sided M.2 2280	Single-sided M.2 2280	Single-sided M.2 2280	
Controller	Samsung Polaris	Samsung Polaris	Samsung Polaris	Samsung Polaris	
Interface	4x PCI-E 3	4x PCI-E 3	4x PCI-E 3	4x PCI-E 3	
Protocol	NVMe 1.2	NVMe 1.2	NVMe 1.2	NVMe 1.2	
NAND	Samsung 48-layer 256Gb MLC V-NAND	Samsung 48-layer 256Gb MLC V-NAND	Samsung 48-layer 256Gb MLC V-NAND	Samsung 48-layer 256Gb TLC V-NAND	
SLC cache	N/A	N/A	N/A	42GB	
Quoted sequential read speed	3,500MB/sec	3,500MB/sec	3,500MB/sec	3,200MB/sec	
Quoted sequential write	2,100MB/sec	2,100MB/sec	2,100MB/sec	1,900MB/sec	
Quoted sequential write (sustained)	N/A			1,200MB/sec	
Quoted 4KB random read (QD32)	440K IOPS	440K IOPS	330K IOPS	380K IOPS	
Quoted 4KB random write (QD32)	360K IOPS	360K IOPS	330K IOPS	360K IOPS	
Endurance	1,200TB	800TB	400TB	400TB	
Warranty	Five years	Five years	Five years	Three years	
Launch price (US)	\$1,299	\$629	\$330	\$479	

performance until the drive is full. In contrast, the Evo range comes with the usual caveat for TLC drives – after a certain point, write speed will drop from those headline figures.

That's because TLC NAND is inherently slow for writes, so TLC drives dynamically convert a portion of the NAND to run in an SLC mode, which is much faster for writing operations. Once that SLC is filled up, though, performance drops back to TLC levels until the drive has a chance to move that data from SLC to TLC.

Samsung calls this SLC buffer TurboWrite, with the 960 Evo drives using a new version dubbed Intelligent TurboWrite. Samsung has remained tight-lipped about what makes it intelligent, but we do know that the size of the SLC has increased significantly compared with the 850 Evo. While the 850 Evo TurboWrite ranged from 3GB to 12GB, the 960 Evo goes from 13GB to 42GB.

It's all managed by Samsung's latest drive controller, Polaris. Samsung has revealed few details about the new controller except that it's largely the same as previous Samsung controllers but now includes five cores rather than the three of the 950 Pro.

The company also revealed that one of these cores is dedicated to optimising communication between the PC's host adapter and the drive's controller. Part of the reason for this optimisation is likely to be that the Pro drives come close to maximising the 4,000MB/sec throughput that can be achieved over the 4x PCI-E 3 connection they use.

To achieve the high capacities, Samsung also had to stack the Pro drives' LPDDR4 DRAM on top of the controller to make room for more NAND packages.

What's more, to keep temperatures in check, Samsung had to add a copper layer to the sticker that covers the chips. This tiny amount of extra heat dissipation, combined with the drive's latest Dynamic Thermal Guard firmware, enables Samsung to keep the drive running at full tilt for a little longer before the firmware throttles performance.

According to Samsung, while the 950 Pro can sustain maximum speed during sequential reads for 63 seconds (158GB) and the 960 Evo can manage 79 seconds (253GB), the 960 Pro can last 95 seconds (333GB).



Note that the drop in performance from thermal throttling is relatively small.

Samsung Magician

Joining these two new drives is a new version of Samsung's Magician software. Along with an updated interface, it includes a few new features that will initially only be available on the new drives. First is a Secure File Erase feature, which adds the ability to securely erase individual files, as an alternative to the existing full-drive erase option. This makes it more convenient to destroy sensitive data without needing to reinstall all their software.

The second feature is Magic Vault, which lets you allocate a portion of the drive to be completely invisible to the OS so it can be used to store sensitive files. It can only be accessed with a password via the Magician software. Third is a system compatibility tab, which will report potential issues with the drive relative to your PC's other hardware. These three additions are joined by the existing features of Magician, which are a full-drive secure erase, firmware updates, performance benchmarks and a drive-health indicator.

We had hoped to feature the 960 Pro drives as a review in this issue, but Samsung changed its review sampling and embargo times to the point where we couldn't test before going to print. Look out for a full review in next month's issue.

EDWARD CHESTER

	SAMSUNG SSD 960 EVO 500GB	SAMSUNG SSD 960 EVO250GB	SAMSUNG SSD 950 PRO 512GB	SAMSUNG SSD 850 EVO M.2 500GB
	Single-sided M.2 2280	Single-sided M.2 2280	Single-sided M.2 2280	Single-sided M.2 2280
	Samsung Polaris	Samsung Polaris	Samsung UBX	Samsung MGX
	4x PCI-E 3	4x PCI-E 3	4x PCI-E 3	4x PCI-E 3
	NVMe 1.2	NVMe 1.2	NVMe 1.2	SATA
	Samsung 48-layer 256Gb TLC V-NAND	Samsung 48-layer 256Gb TLC V-NAND	Samsung V-NAND 32-layer 128Gbit MLC	Samsung V-NAND 32-layer 128Gbit TLC
	22 GB	13GB	N/A	6GB
	3,200MB/sec	3,200MB/sec	2,500MB/sec	540MB/sec
	1,800MB/sec	1,500MB/sec	1,500MB/sec	500MB/sec
	600MB/sec	300MB/sec	N/A	500MB/sec
	330K IOPS	330K IOPS	300K IOPS	97K IOPS
	330K IOPS	300K IOPS	110K IOPS	89K IOPS
	200TB	100TB	400TB	150TB
	Three years	Three years	Five years	Five years
	\$249	\$130	\$350	\$249

ATX MOTHERBOARD

Asus Rampage V Edition 10 / £516 inc VAT

SUPPLIER www.scan.co.uk

Asus' Rampage V Edition 10 is the second X99 board to bear the 'Rampage V' moniker, with the second part of the name denoting the fact that ROG is celebrating its tenth anniversary – congratulations Asus. However, unlike some of the recent Z170 and X99 refreshes, the Rampage V Edition 10 is a very different board to its predecessor. Gone is the familiar red and black colour scheme, and in its place is a mostly black PCB that's similar to the Maximus VIII Formula, with colour coming from RGB LED lighting.

With a colour-neutral motherboard, you can switch the lighting to practically any colour, easily matching the Rampage V Edition 10 to the colour scheme of your system. Asus' RGB lighting has been consistently excellent, with

very accurate colours and the Rampage V Edition 10 has even more lighting areas than the Maximus VIII Formula, with a large strip down one side, plus the PCI-E slot levers, PCH heatsink ROG logo, sound circuitry and I/O panel are all illuminated.

The PCI-E slot levers also indicate the correct slots to use for two, three and four-way GPU setups for the best bandwidth and cooling. A small lever on the board allows you to switch to the desired configuration, with the levers lighting up accordingly. There's a huge gap between the primary and secondary 16x PCI-E slots too, so air-cooled cards will have plenty of clearance for airflow.

As well as four 16x PCI-E slots, you also get a 1x PCI-E slot and a 4x PCI-E slot, which may be handy for adding a PCI-E storage device; the Rampage V Edition 10 only includes single M.2 and U.2 ports, and no PCI-E adaptor. Meanwhile,

Asus has sensibly ditched SATA Express with the Rampage V Edition 10, and there are ten standard SATA 6Gbps ports. Thankfully, it's unlikely you'll need either of those aforementioned smaller PCI-E slots for a sound card. As well as the usual Realtek-based SupremeFX audio, the board includes a 5.25in amplifier box with headphone jacks and a microphone input.

Other accessories include custom two, three and four-way SLI bridges, a 4-channel PWM fan extender that can be controlled in the EFI, a Wi-Fi desktop aerial and an RGB LED extension cable for the single on-board 4-pin led header. The latter can be controlled either by the included Windows Aura software, or in the EFI. In the EFI, you can only choose from a dozen or so colours, or turn off the lights, while the Aura

software gives you the full RGB colour spectrum and splits the lighting into various zones.

You get a huge array of overclocking and testing tools too, including voltage readout points, a dual BIOS switch, power and reset buttons, and a few controls for sub-zero cooling and extreme overclocking, such as the ability to disable individual DIMM or PCI-E slots to quickly swap hardware or identify faulty items. We did spot some issues with the layout, though, such as the 8-pin CPU power connector on our Corsair PSU rubbing up against the VRM heatsink, pushing both parts outwards. It's also impossible to release most graphics cards in the primary PCI-E slot with your fingers, as the gap is only a few millimetres wide.

On the plus side, the rear panel is bristling with ports and includes two Intel Gigabit Ethernet ports, three USB 3 ports and a pair of USB 3.1 Type-A and Type C ports, along with a clear-CMOS button and another button for Asus' USB BIOS flashback feature, which allows you to install a new BIOS without using a CPU.

The EFI itself is excellent, with a mass of options for extreme overclockers, while also making it easy to apply a reasonable overclock in a few seconds. The fan control suite, as with all current Asus ROG boards, is superb too.

Performance

The Rampage V Edition 10 continued Asus' strong form at stock speed thanks to some aggressive CPU boosting once we'd set the XMP profile in the EFI. Its total system score of 163,531 is way ahead of even its nearest rival – the Asus X99-Deluxe II, which managed 159,273. MSI's XPower Gaming Titanium and Gigabyte's X99 Design are noticeably



/SPECIFICATIONS

Chipset Intel X99**CPU socket** Intel LGA2011-v3**Memory support** 8 slots: max 128GB DDR3 (up to 3333MHz)**Expansion slots** Four 16x PCI-E 3, one 1x PCI-E 2, one 4x PCI-E**Sound** ROG SupremeFX**Networking** Intel I218-V Gigabit LAN, Intel I211-AT Gigabit LAN, 802.11ac Wi-Fi**Overclocking** Base clock 80–300MHz, CPU multiplier 12–80x; max voltages, CPU 2V, RAM 2.155V**Ports** 10 x SATA 6Gbps (Z170), 1x M.2, 1x U.2, 8x USB 3, 2x USB 3.1 Type-A, 2x USB 3.1 Type-C, 6x USB 2, 2x LAN, 3x surround audio out, line in, mic, (extra 3.5mm and 6.3mm audio out and mic via SupremeFX HiFi)**Dimensions (mm)** 305 x 272

slower, with similar results in Total War: Warhammer. There were no issues in storage tests either, with read and write speeds of 2,300MB/sec and 957MB/sec for the M.2 port using a Samsung 950 Pro, while the SATA 6Gbps ports sat around the respective read and write speeds of 559MB/sec and 528MB/sec using a Samsung 850 Pro.

The audio performance was average using the on-board audio ports on the I/O panel, but switching to the SupremeFX HiFi amplifier saw the dynamic range and noise levels improve. The former rose from 103dBA to 110dBA according to RightMark Audio Analyzer, while the noise level fell from -103dBA to -110dBA. This result is the best we've seen from any motherboard using our standard RightMark test. In terms of overclocking, our usual 800MHz overclock to 4.4GHz with our Core i7-6850K was easily achieved with just a 1.36V vcore – using custom water cooling would likely see this result rise further too, as only the temperature prevented us from going further.

Conclusion

The Rampage V Edition 10 is hugely expensive, but also very desirable. It isn't perfect – there's no way to use two U.2 or



1 Gone is the familiar red and black colour scheme, replaced by a black PCB

2 There are loads of overclocking and testing tools, including voltage readout points, a dual BIOS switch, and power and reset buttons

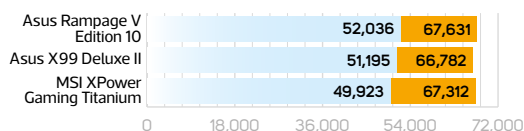
3 The position of the 8-pin CPU power connector can result in your power plug rubbing up against the VRM heatsink

M.2 drives and the layout has a couple of issues, but otherwise, it has every feature you need to build a mega PC. Asus has once again combined performance, overclocking prowess, features and great aesthetics to create a king of the X99 platform.

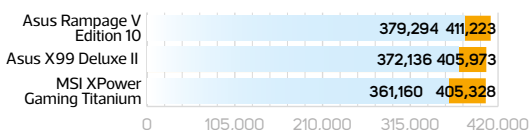
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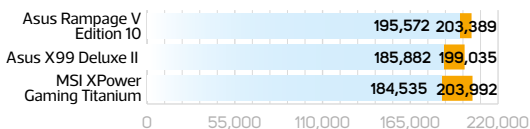
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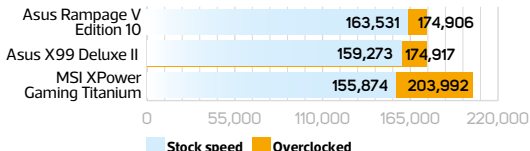
HANDBRAKE H.264 VIDEO ENCODING



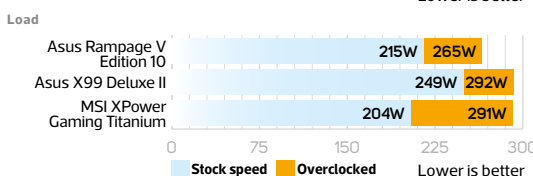
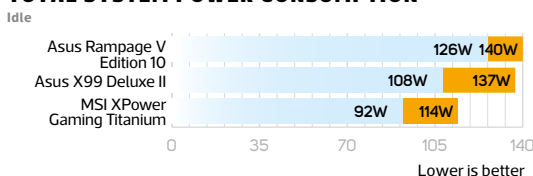
HEAVY MULTI-TASKING



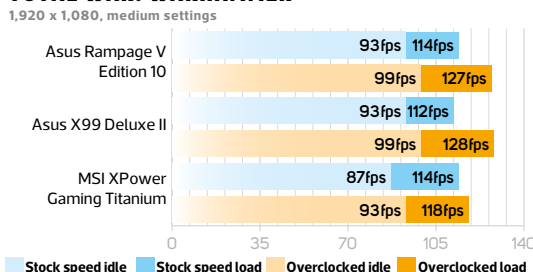
SYSTEM SCORE



TOTAL SYSTEM POWER CONSUMPTION



TOTAL WAR: WARHAMMER



SPEED
38/40
VALUE
22/30

FEATURES
27/30

OVERALL SCORE
87%

VERDICT

Stunning RGB lighting, excellent audio, and great performance and features make for a superb motherboard, although it's very expensive.

ATX CASE

DeepCool Genome II / £230 inc VAT

SUPPLIER www.amazon.co.uk

At Custom PC we've built dozens of water-cooled rigs over the years, and whether we're building a custom system, filling the loop with coolant or just fitting an all-in-one liquid cooler, it can all be a pain. Large radiators can be tricky to install, which is unavoidable if you opt for an all-in-one (AIO) liquid cooler. DeepCool, though, has a way to make the whole process much easier with a pre-water-cooled case. The first Genome was released earlier this year, and here, we're reviewing its successor, the Genome II, which features a few useful additions.

At £230 inc VAT, it clearly isn't cheap. You can easily buy a similar cooling setup and a half-decent case for less money. However, rather than opt for a standard AIO cooler, DeepCool

has added a separate reservoir – a feature that's lacking from any AIO cooler we've seen. The reservoir is situated in the front of the case in purpose-made housing, so it's clearly visible. Sadly, though, while it looks great with the internal green acrylic tubing, and is available in a range of colours (with the red shown on p18), there's no coolant frothing around inside. The coolant only passes through these tubes, so it all looks a little static.

It's a flashy touch of pizzazz nonetheless though.

The case is made from steel and plastic. It feels sturdy, but there's a little too much plastic on the exterior. Meanwhile, the interior is dominated by a massive triple 120mm-fan radiator in the roof, which is cooled by three pre-installed, white LED fans. Your only job is to connect the fans and install the CPU cooler on your motherboard. There's also a 120mm fan in the rear, and all the fans have fluid dynamic bearings and act as exhausts. They're also all powered by 4-pin PWM sockets and DeepCool has included a 4-channel PWM hub so you can power them all from a single fan header. The hub

can be attached anywhere in the case too, using a bundled adhesive strip.

Then there's the CPU cooler, which is a customised version of DeepCool's Captain 360, sporting a U-shape section of tubing that's mostly just for show, but livens up the otherwise all-black exterior. Thankfully, once powered on, the centre of the pump section lights up, making for one of the best-looking AIO coolers we've seen. Installation is simple too. You should be able to install the pump section with the motherboard installed in the case, thanks to a large CPU area cutout in the motherboard tray that's big enough to fit the cooler backplate through it. A couple of metal mounting plates attach to pins protruding through the CPU side of the PCB, allowing you to screw two mounting pins on the pump section into them, fixing the pump section onto the CPU.



The reservoir looks great with the green acrylic tubing

The case has decent ventilation too, and DeepCool has included some substantial holes in the roof to allow the radiator to expel hot air fairly freely, although it isn't quite as effective as a proper mesh section or fan grille.

The front of the case sports more of the same chunky cut-outs, but sadly, this section lacks a removable dust filter. The front panel can be removed, though, revealing the detachable reservoir, and there are at least some fixed filters that will need occasional cleaning.

The base also includes a removable filter for the PSU, while the only fan mounts that aren't filled are located in the front. DeepCool has added a 200mm fan mount to the front in this second version of the chassis as well, and there are two 120mm fan mounts here too, plus space for a further radiator, even if the cooling loop isn't easily expandable and mostly sealed. Meanwhile, storage bays include a pair of 3.5in bays in a small cage in the base and two dedicated 2.5in trays attached to the rear of the motherboard tray.

Cable routing has also been improved compared with the previous case, with more space behind the motherboard tray, while a large PSU cover hides most of the cables and two rubber grommets allow the 24-pin ATX connector, SATA cables and PCI-E power cables to pass through to the motherboard.

Interestingly, one of the main selling points of the case, aside from the cooling system, is the ability to flip the graphics card on its side using a PCI-E riser cable. This feature wasn't included with the original model, but DeepCool now bundles a riser with the Genome II. It plugs into your motherboard at one end, then secures to your case near the side window at the other. It has a large support base too, which screws directly onto the case, so there's no chance of your graphics card wobbling around. If your graphics card has an attractive cooler or waterblock then this riser will give you a great view of it through the side window.

/SPECIFICATIONS

Dimensions (mm) 210 x 505 x 506 (W x D x H)

Material Steel, plastic

Available colours Black, white

Weight 9.77kg

Front panel Power, reset, 2 x USB 3, stereo, mic

Drive bays 2 x 3.5in, 2 x 2.5in

Form factor(s) ATX, micro-ATX

Cooling 3 x 120mm or 2 x 140mm roof fan mounts (3 x 120mm fans and radiator included), 2 x 120mm / 1 x 200mm front fan mounts (fans not included), 1 x 120mm rear fan mount (fan included)

Maximum graphics card length 330mm



- 1** The interior is dominated by a massive triple 120mm-fan radiator in the roof
- 2** The CPU cooler is a customised DeepCool Captain 360, sporting a U-shaped tubing section
- 3** You can flip your graphics card on its side using a PCI-E riser cable

Performance

As the Genome II sports an integrated CPU cooler, we decided to ditch our usual testing method and perform a one-off test instead. Using an overclocked Intel Core i7-6700K and an AMD R9 390X graphics card, we fired up Unigine Heaven and Prime95 to see how the case coped, before removing the side panel to fit an NZXT Kraken X61 CPU cooler to roughly gauge how well the DeepCool cooler performs. With the side panel off, the CPU delta T was just 4°C cooler, so the large case vents clearly did a reasonable job of allowing air into and out of the case.

With the side panel off, the NZXT Kraken X61 managed to outperform the bundled cooler by 4°C, although it was considerably louder. In fact, both the DeepCool fans and pump were exceptionally quiet when idle. The graphics card was kept at a delta T of 51°C with the side panel on, mounted on its side, with this result falling to 47°C with the card mounted normally to the motherboard, and further still to 44°C with the side panel removed. It's clear that mounting

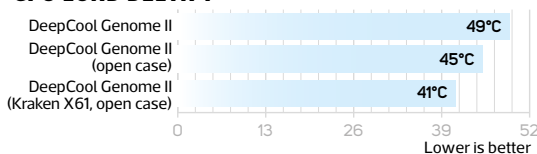
your graphics card on its side close to the side panel does impact on cooling, and the case would also benefit from a front intake fan.

Conclusion

The Genome II offers a unique look compared with your average PC with an AIO liquid cooler, thanks mostly to the attractive reservoir. Cooling is good, although not spectacular for such a large cooler, but it's also very quiet. If all the bits were sold separately, the case would likely cost around £60, the cooling system around £140 and the PCI-E riser cable another £30, although using the latter may see your GPU run hotter. As such, while you could save money by buying a separate case and AIO cooler, the Genome II still offers fairly good value for money, while also giving you an attractive, quiet and easy-to-build system. It isn't perfect, but if you have the money, want an easy setup process and like its looks then the Genome II won't disappoint you.

ANTONY LEATHER

CPU LOAD DELTA T



GPU LOAD DELTA T



COOLING
25/30

FEATURES
17/20

DESIGN
25/30

VALUE
16/20

OVERALL SCORE
83%

VERDICT

The Genome II comes nearly ready to run, looks great when powered up and is very quiet. It's a good buy, although you can liquid-cool better cases for less money.

ATX CASE

Thermaltake Core G3 / **£70** inc VATSUPPLIER www.scan.co.uk / MODEL NUMBER CA-1G6-00T1WN-00

We haven't reviewed many cases that require small SFX PSUs, and the ones we have seen are usually small mini-ITX cases, where the manufacturer has taken the bold leap to ditch normal PSU compatibility to save space. However, Thermaltake's Core G3 supports full-sized ATX motherboards, yet its super-slim chassis is made possible by it being limited to SFX PSUs.

The PSU mount is at the bottom of the case on its side, shaving a good couple of inches off the width compared with using a full-sized ATX PSU mount. In addition, Thermaltake has bundled a shielded PCI-E riser cable for your graphics card, so it can be flipped on its side, much like the Deepcool Genome II we also reviewed this month (see

p24). In the Core G3, though, the graphics card sits just an inch or two above the motherboard. This whole setup means the Core G3 has an incredibly narrow width of just 14cm, although there are no additional expansion slot mounts.

As such, this setup rather defeats the point of using an ATX motherboard, as there's no space for sound cards or other expansion cards, although you can at least

transplant your current motherboard and hardware to save some cash, minus your ATX PSU, of course. There are also often other bonuses to full-sized ATX boards besides the extra expansion slots, such as multiple M.2 sockets and more DIMM slots than mini-ITX boards. The design is obviously great if you need a PC with a small footprint, but Thermaltake also includes rubber case feet that you can attach to the side, so you can lay the case flat in desktop mode, with the large side panel window facing up.

The case itself is fairly plain, but it has excellent ventilation, with large mesh grilles in the base, roof and front, all three of which sport dust filters. The filters on the roof and base are magnetic and easily removable, but the front filter is hidden behind the front panel, which needs to be popped off to access the filter.

The front panel has two USB 3 and two USB 2 ports, a large power button, a reset button and audio mini-jacks. There's no fan controller or hub, though, and no lighting either. Plus, to keep the case width to a minimum, there's no space behind the motherboard tray for tucking cables. Accordingly, there are no cable-routing holes, so you'll need to pay careful attention to cable tidying if you want a neat system. Thankfully, the cables on SFX PSUs are usually fairly short, plus the case only has space for a single graphics card and two storage drives, so you shouldn't be dealing with too many cables anyway.

The storage bays are located in a small cage in the front of the case, but these bays also



require the removal of the front panel, which gives access to slide-out trays that can accommodate either a 3.5in hard disk or a 2.5in SSD. There are also two 120mm fans mounted as intakes in the front, while a further 120mm mount is found in the roof. Amazingly, despite its size, the Core G3 can house a double 120mm radiator in the front too, with enough depth for two rows of fans on slim radiators. These radiator mounts will potentially be life-savers for high-end overclocked systems, though, as the CPU cooler height limitation is just 110mm, meaning you'll otherwise be limited to low-profile coolers.

There's room for a 310mm graphics card, though, so most high-end cards will fit fine. Unlike the Deepcool Genome II, though, the Core G3's PCI-E riser cable isn't attached to the case and simply trails from the motherboard.

As a result, only the rear PCI-E expansion slot provides physical support, which is why the box includes two adjustable padded supports that you can place on either side of your graphics card to hold it in place from below and the sides. It isn't particularly elegant, and some cards with side-mounted power connectors will end up with the support pressing on the power cables rather than the graphics card itself, but it's enough to prevent dangerous flexing, especially if you move your PC a lot.

Performance

With the Core G3 only supporting low-profile CPU coolers, we were limited to using our mini-ITX test kit, which uses a Zalman CNPS 8900 low-profile cooler, but you'll see much better results if you opt for an all-in-one liquid cooler. Even

/SPECIFICATIONS

Dimensions (mm) 140 x 371 x 454 (W x D x H)

Material Steel, plastic

Available colours Black

Weight 4.2kg

Front panel Power, reset, 2 x USB 3.0, 2 x USB 2.0, stereo, mic

Drive bays 2 x 3.5in / 2.5in

Form factor(s) ATX, micro-ATX, Mini-ITX

Cooling 2 x 120mm front fan mounts (2 x 120mm fans included), 1 x 120mm roof fan mount (fan not included)

CPU cooler clearance 110mm

Maximum graphics card length 310mm

1

The Core G3's slim width is achieved by using an SFX PSU mount in the bottom of the case

2

There are no cable-routing holes, so you'll need to pay careful attention to cable tidying

3

A PCI-E riser flips the graphics card on its side, but you won't be able to use any other PCI-E slots



so, the CPU delta T of 58°C is fine, beating the likes of NZXT's Manta and Phanteks' Enthoo Evolv ITX, largely due to the excellent amount of airflow drawn into the case and its mass of ventilated panels.

However, most of the tower cases on test can also house tower air coolers, which would perform better than our usual low-profile cooler.

The GPU delta T of 50°C is again a good result, although airflow is limited with the GPU's fan sitting so close to the side panel. Even so, this result came close to matching those of NZXT's Manta and Fractal Design's Define Nano S. The fans, meanwhile, were relatively quiet at full speed and shift a good deal of air, although we'd advise adding another fan to the roof to expel the warm air.

Conclusion

Despite its rather basic, no-frills design and average cooling, the Core G3 is very interesting. By using SFX PSUs, Thermaltake has made the case much smaller than your average ATX tower, saving a huge amount of desk space, yet still enabling you to build a high-end system.

Mounting the graphics card on its side also means you get a great view of it through your side panel, and there's loads of room for water-cooling gear, or an all-in-one liquid cooler, as well. On the downside, you won't be able to use any of

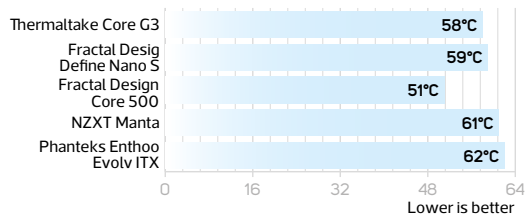


your ATX motherboard's other expansion slots, which is perhaps this case's biggest issue.

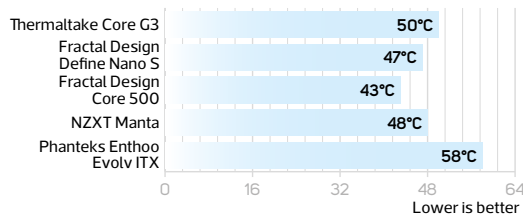
The case is solidly built too, and the £70 asking price is quite reasonable for an ATX case that includes a shielded PCI-E riser cable. If you're looking for a different case design, or just need a space-saving home for an ATX system, and you don't want to fill up your machine with expansion cards, then it's a good choice, especially if you use an all-in-one liquid cooler, and we commend Thermaltake for trying a new idea too.

ANTONY LEATHER

CPU LOAD DELTA T



GPU LOAD DELTA T



COOLING
24/30

FEATURES
17/20

DESIGN
26/30

VALUE
17/20

OVERALL SCORE
84%

VERDICT

A truly different case design that not only saves space but still offers room for a high-end, liquid-cooled ATX PC, although you can only install one graphics card.



Performance without compromise



Spectre Lite

- AMD FX-4300
- ASUS® M5A97 R2.0
- 8GB HyperX FURY RAM
- 2GB NVIDIA® GeForce® GTX 950
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- Corsair 350W PSU
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- 3 Year Standard Warranty

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- Windows 10
- 3 Year Standard Warranty

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- Liquid Series Entry Kit
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- 500GB Samsung 750 SSD
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- Windows 10
- 3 Years Warranty

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- Wireless as standard
- Windows 10
- 3 Year Standard Warranty

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GAMING LAPTOP

Scan 3XS LG17 Carbon Extreme / £2,550 inc VAT

SUPPLIER www.scan.co.uk

Scan's new LG17 Carbon Extreme is one of the most monstrous mobiles we've seen. It sports Nvidia's latest mobile GPU alongside a desktop CPU, and it's topped off by a 4K screen. The mobile GeForce GTX 1080 isn't the usual cut-down affair either. The efficiency improvements in Nvidia's Pascal architecture mean that Nvidia's flagship mobile chip has 2,560 stream processors, just like the desktop equivalent.

The mobile GTX 1080 has base and boost clocks of 1556MHz and 1733MHz by default, but in this laptop, those figures are dynamically improved to 1582MHz and 1771MHz. This mobile graphics card also retains

the 8GB of 10GHz GDDR5X memory found on the desktop card.

This huge graphics ability connects to a 17.3in 4K screen, which supports Nvidia's G-Sync tech. It isn't the first laptop with a 3,840 x 2,160 screen, but it may well be the first one with the power to make use of all those pixels in games.

Meanwhile, the Core i7-6700K is another muscular component. It's a

desktop part, so it has the full 4GHz clock speed. The other components fall into familiar laptop territory. There's 16GB of DDR4 RAM, which is plenty, although the 2133MHz speed is a little slow. There's also a super-quick 256GB Samsung 950 Pro SSD, which is paired with a 2TB hard disk.

It's all packed into a chassis made by Taiwanese manufacturer Clevo, which sports a smart Scan 3XS logo on the lid. There's an attractive brushed-metal section near the

hinge, and more brushed metal is revealed once the lid is eased open. The smart metal sits alongside two speaker grilles, the power button and a row of status lights.

The back edge also has aggressive-looking vents, but that's it in terms of ostentatious 'gamer' design – it's otherwise a smart, low-key laptop.

The keyboard has a blue backlight too, along with a full-sized numeric keypad, and no shrunken buttons. It's a high-quality typing unit – the action strikes a good balance between a soft, comfortable press and the firmer click you get from mechanical keyboards. The touchpad is decent as well. There's no friction, and the buttons have good travel and a fast clicking motion, although you'll want a USB mouse for most games. The location on the left is a concern, though, making it possible to knock the pad while gaming with the WASD keys.

There's no give in the wrist-rest, though, and the sturdy screen barely moves when

flexed, keeping the 4K panel protected. The underside is also strong, and its panels pull away to give access to the cooling system, components, and spare SATA and M.2 connectors. The whole unit feels very solid, which bodes well for LAN parties, but it comes with the usual desktop replacement caveat – size and weight. This machine weighs 4.3kg, and it measures 39mm thick, making it thicker and heavier than most other gaming laptops.

Elsewhere, Scan has crammed Killer Ethernet, dual-band 802.11ac Wi-Fi and the sound system is controlled by Creative's Sound Blaster X-Fi MB5 software. There are two speakers and a subwoofer, and the sound is good – loads of bass underpins a meaty mid-range, with slightly distorted high-end sounds being the only obvious weakness.

As ever, most of the components can be changed too. Core i5 options are available, more SSDs can be added and memory capacity can be doubled or halved. The screen can be replaced with a cheaper 1080p panel too. It's well covered as well – every Scan laptop comes with a two-year warranty covering both parts and labour, and that deal includes collect and return service for the first year.

Performance

The GTX 1080 delivers desktop-level performance. It romped through our Witcher 3 4K benchmark without dropping below 41fps, and it stayed above the borderline playable 25fps barrier in Fallout 4 and Crysis 3 – you'll only need to drop the settings a little in these games to make them smoothly playable at the native resolution. G-Sync also makes these games look great, removing any stuttering and tearing.

The Core i7 CPU is a great performer too. It isn't overclocked, but it still produced benchmark score of 127,423, showing that it's fast enough to handle demanding software and games. The SSD is rapid too, with sequential read and write speeds of 2,098MB/sec and 1,534MB/sec.

Heat and noise is always a concern in laptops, even with efficient Pascal and Skylake components, and Scan's



SPECIFICATIONS

CPU 4GHz Intel Core i7-6700K

Memory 16GB 2133MHz DDR4

Graphics Nvidia GeForce GTX 1080 8GB

Screen 17.3in 3,840 x 2,160 Nvidia G-Sync IPS

Storage 256GB Samsung 950 Pro M.2 SSD, 2TB hard disk

Networking Gigabit Ethernet, dual-band 802.11ac Wi-Fi

Weight 4.3kg

Ports 4 x USB 3, 2 x USB 3.1 Type-C, Gigabit Ethernet, 4 x audio, SD card slot, HDMI, 2 x mini-DisplayPort

Dimensions (mm) 418 x 282 x 39 (W x D x H)

Operating system Windows 10 Pro 64-bit

Warranty Two years parts and labour, with first year collect and return and second year return to base



machine operates near the edge during stress tests. The CPU and GPU delta Ts of 74°C and 63°C are high, and the GTX 1080 couldn't reach its top boost speed, peaking at 1683MHz. Those temperatures are high, but not dangerous – and the exterior didn't heat up, with the majority of hot air vented through the system's rear. It isn't too loud either; the fans produce a low-pitched, consistent hum.

Meanwhile, the 4K screen is a good-quality unit beyond its pixel count. Its 354cd/m² brightness is huge, and its black level of 0.32cd/m² makes darker tones punchy. The 1,106:1 contrast ratio is plenty, and the colour temperature and delta E of 7,134K and 4.46 are reasonable. The real star, though, is the sRGB coverage of 100 per cent, which means every shade in this gamut can be reproduced.

We toned down the panel to a more realistic 150cd/m² brightness, and the colour temperature improved to 6,876K and the delta E jumped to 1.28 – a stunning figure. Contrast remained consistent, and the screen's uniformity test saw

a sub-10 per cent brightness deviation in most segments – an above average result.

Battery tests saw the Scan clatter back to earth though. It couldn't manage a full hour when gaming, and lasted around 90 minutes during application tests.

Conclusion

Nobody buys gaming laptops for battery life, though, and the Scan 3XS LG17 Carbon Extreme delivers its promise of all-out performance, managing playable frame rates in our test games at its native 3,840 x 2,160 resolution, and it will only require minor tweaking to get these games running even smoother.

It also has a good keyboard, exceptional build quality, smart design and a decent screen. It's big, heavy and expensive, of course, but it delivers the goods if you want the absolute best kit for gaming on the go.

MIKE JENNINGS

CPC REALBENCH 2015 GIMP IMAGE EDITING



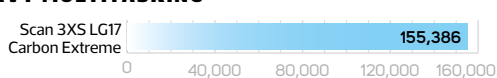
HANDBRAKE H.264 VIDEO ENCODING



LUXMARK OPENCL



HEAVY MULTITASKING



SYSTEM SCORE

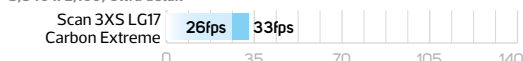


INTEL REFERENCE: 111.33%

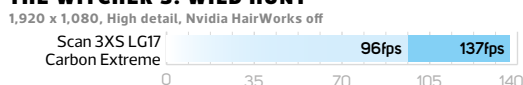
FALLOUT 4



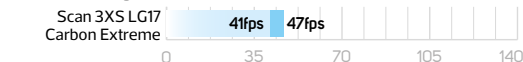
3,840 x 2,160, Ultra detail



THE WITCHER 3: WILD HUNT



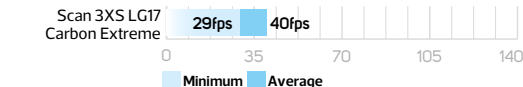
3,840 x 2,160, High detail, Nvidia HairWorks off



CRYSIS 3



3,840 x 2,160, Very High detail, 0x AA



Minimum Average

SPEED
24/25

DESIGN
21/25

HARDWARE
23/25

VALUE
22/25

OVERALL SCORE
90%

VERDICT

Exceptional gaming power and excellent components combined with a great screen and solid build – just don't expect this machine to be light or cheap.

27IN GAMING MONITOR

BenQ Zowie XL2730 / £470 inc VAT

SUPPLIER www.laptopsdirect.co.uk

BenQ's Zowie XL2730 is aimed at eSports, which is why it uses a TN panel, giving it an edge over IPS displays for response times. It also has a 144Hz refresh rate, but it doesn't have AMD FreeSync or Nvidia G-Sync. The huge refresh rate should be great for eSports, because frames will be displayed as quickly as the GPU can produce them, but you'll only get the best results with frame rates close to 144fps, so you'll need a beefy GPU.

The 2,560 x 1,440 panel has a matt finish, and the sturdy stand offers height, swivel and tilt adjustment. It can swing to portrait mode, and also sports cable-routing holes and a carrying handle.

Meanwhile, the physical OSD control buttons are more tactile than touch-sensitive pads, and the left edge of the monitor offers USB and audio ports alongside a headset

holder. Assembly is easy, and the S Switch remote control is handy for switching between screen modes. These modes are aligned to game genres, and there are also tools to reduce blur, brighten darker areas and improve vibrancy. Sadly, none of the controls is effective – the blur reduction makes the picture darker and

grainier, the black equaliser just changes the brightness and the colour vibrancy tool merely makes colours look oversaturated.

First performance impressions weren't great either, with an overly bright and washed-out image. Our tests backed up that impression, revealing a cool 11,102K colour temperature and a disappointing delta E of 5.07. The brightness level of 274cd/m² is fine, but the 0.35cd/m² black level is high, showing that the contrast ratio of 782:1 isn't good enough. Dropping the brightness to a reasonable 150cd/m² didn't help, but activating the screen's Dynamic Contrast mode saw the colour temperature and contrast ratio improve to 8,272K and 957:1 – not great, but better.

The initial results aren't surprising considering the default mode is for FPS gaming, although the other game genre modes weren't much better either. We had more success

with BenQ's customisable Gamer options, where delta E results were still average, but we could improve the colour temperature and contrast to around 6,800K and 1,030:1 – superior to the genre modes, and noticeable on the panel.

However, we achieved the best results by abandoning the gaming modes. The Standard option saw a 7,168K colour temperature, 1,011:1 contrast ratio and reasonable delta E of 2.22. The improved results are obvious, with a balanced and punchy image, with no sign of washed-out colours or a chilly blue hue.



There are still inconsistencies from the TN panel though. The colour temperature varies by 21 per cent along the top and has single-figure swings elsewhere. Unlike your average IPS panel, viewing angles aren't great either, with the tone of lighter colours changing in the corners. The backlight bleeds a little from the bottom too.

It's great in games though. We ran Crysis 3 and Fallout 4 at high frame rates and found the XL2730 to be extremely smooth – almost as smooth, in fact, as a screen with active sync tech – we found it tough to spot any tearing in our tests.

Conclusion

The XL2730's TN panel and 144Hz refresh rate handle games quickly and smoothly, and the Zowie is packed with practical features, while being easy to assemble and carry. You sacrifice image quality, however. The conventional modes are better than the Zowie's gaming modes, but they aren't great, and the viewing angles and uniformity issues are a hindrance. The Zowie gives competitive gamers a very fast screen, but if that isn't your absolute top priority, we'd buy a more consistent, similarly priced, IPS screen instead.

MIKE JENNINGS

/SPECIFICATIONS

Screen size 27in

Native resolution 2,560 x 1,440

Maximum refresh rate 144Hz

Panel tech TN

Inputs 1 x DisplayPort 1.2a, 2 x HDMI 2, 1 x DVI, 1 x D-SUB

USB 1 x USB 3 input, 3 x USB 3 outputs

Power supply Internal

OSD control Touch-sensitive buttons and USB controller

IMAGE QUALITY

38/50

FEATURES

18/20

VALUE

22/30

OVERALL SCORE

78%

VERDICT

A high refresh rate, fast gaming performance and plenty of features, but you sacrifice image quality in the process.

www.ebuyer.com/pc-builder

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Unique to you



Custom Kit

Paul Goodhead checks out the latest gadgets, gizmos and geek toys

CARD GAME

Coloretto / £8 inc VAT

If you only gave Coloretto a passing glance you might assume it was just a simple kids' game. There are very few rules; the game simply involves collecting coloured cards from three central piles and it's all dressed up with slightly childish chameleon artwork.

You'd realise you were wrong about mid-way through your first play-through, however. A game of Coloretto, which takes around 20 minutes, plays like a cross between Poker and Rummy, although you can see your opponents' cards.

Each turn requires a careful balancing calculation between building a pile for yourself and blocking off colours your opponents want, while remembering which cards have been claimed and which cards are left in the deck. With its cheap price, portability and simplicity, it's an easy recommendation.



SUPPLIER www.amazon.co.uk



ACTION CAM

Sony HDR-AS50 / £179 inc VAT

GoPro is dominant in the world of action cameras, but if anyone has the know-how and money to compete, it's Sony. Priced at £179 inc VAT, the AS50 currently costs £20 more than a GoPro Session – the latter's price has dropped dramatically from its £330 RRP a year ago. In some areas, the more modern Sony has the edge too – it has longer battery life, built-in digital image stabilisation and a much better UI. However, in the ways that matter most, it loses out. It's heavier than the Session, it needs a separate waterproof case, it's bulkier and, crucially, the image quality isn't as good. The dynamic range of the AS50 shots was narrower than that of the GoPro, making video look dull in comparison. We recommend opting for the GoPro Session instead, and spending the extra £20 on some accessories.



SUPPLIER www.sony.co.uk



BLUETOOTH SPEAKER

Libratone Too / £109 inc VAT

Libratone's Too is deliberately modelled to be a similar shape and size to that of a drinks bottle, so the speaker fits neatly into the side mesh pockets on backpacks, bike bottle holders and other slots designed for drinks. Of course, not many bottles of water cost £109; we'd certainly think twice before wandering around with it hanging off the side of a bag rather than zipped safely within. In use, the Too was competent rather than classy, though, which is a letdown given the price. Low tones lacked the presence of the similarly sized and priced UE Boom 2 and volume wasn't as plentiful either. Libratone suggests pairing a couple of Toos together using the Libratone app if you need more volume, but for that £220 price, you'd be better off buying one ace speaker, rather than two average ones.



SUPPLIER www.libratone.com

ROBOT HOOVER

Samsung Powerbot VR9300 / £799 inc VAT

Samsung claims that the Powerbot VR9300's motor is the most powerful one the company has ever put in a robot, and its performance bears out this claim. Carpets were left clean and brushed, and route finding is good too, thanks to the bot's myriad sensors. For a laugh, you can control the unit manually with the bundled remote, terrorising pets and guests in the process.

These features all add to the eye-watering price, but they work. The VR9300 only got stuck once in the week we had it, and its coverage was reliably good. If you're simply in love with the idea of a robot trundling around your home doing your bidding, and you have the money, the Powerbot VR9300 is the best robot vacuum cleaner we've seen.



SUPPLIER www.samsung.com



EXTERNAL HARD DISK

My Passport Wireless Pro 3TB / £210 inc VAT

Giving the Passport Wireless Pro an 'external storage' label sells it rather short – it's more like a miniature 802.11ac Wi-Fi NAS with a 12-hour on-board battery. Aimed at professional photographers and videographers, the Pro stores files without the need for a PC. It connects directly to a camera via USB or Wi-Fi, with files selected and copied via the free (smart, rather than stylish) smartphone app. If that isn't your style, it will also automatically copy files from an inserted SD card, which fits well with a photographer's workflow.

As a party trick, the drive also functions as a standalone Plex or DLNA server, streaming on-board media to a smart TV, Roku device or Chromecast. It's a tidy package that works well, although it's a little overpriced for what's on offer.



SUPPLIER www.store.wdc.com



POWER BANK

Aukey PB-N36 20000mAh / £28 inc VAT

Given its whopping 20,000mAh capacity, £28 inc VAT is a relatively small sum for the Aukey PB-N36. It's not as if you're getting a bargain basement unit either, as the PB-N36 is attractively finished and has some clever touches. At the top of this list is the inclusion of both micro-USB and Lightning power input ports, meaning iOS users don't have to carry an extra cable to recharge the battery.

Meanwhile, the two 2.4A USB output ports can pump out juice to connected devices simultaneously, while a coloured light behind the power button indicates the remaining charge. On our test bench, the Aukey recharged our test Nexus 5X phone four times without even dropping down to 30 per cent charge, making it an ideal accessory for a festival weekend or a family camping trip.



SUPPLIER www.amazon.co.uk



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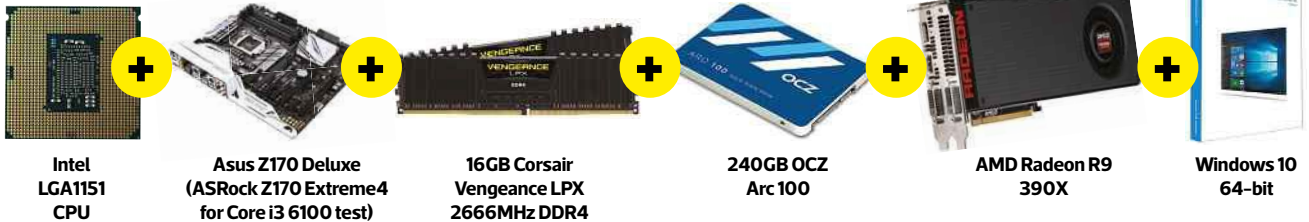
How we test

Thorough testing and research is the key to evaluating whether a product is worth buying, and deciding whether or not there's a better alternative

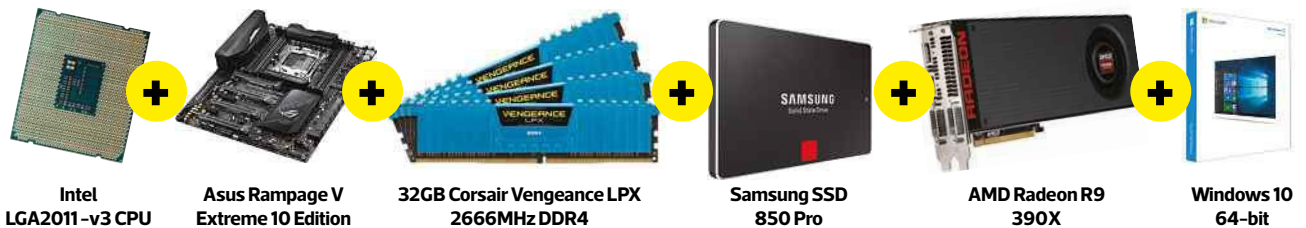
PROCESSORS

We judge CPUs on whether they offer sufficient speed for the price. Part of a CPU's speed score comes from how overclockable it is. Every type of CPU is tested in the same PC, so all results are directly comparable.

INTEL LGA1151



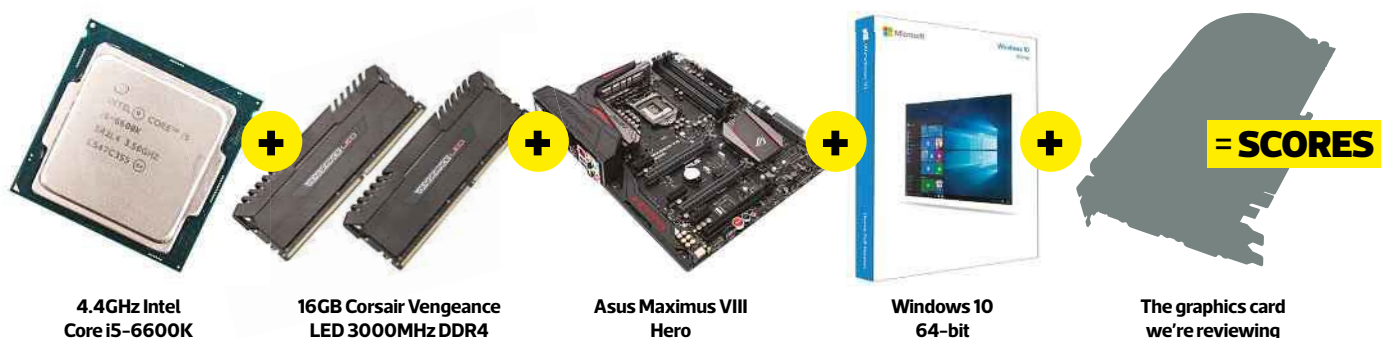
INTEL LGA2011-V3



TESTS: We use Custom PC RealBench 2015, Cinebench R11.5 and a variety of games. We also test the power draw of the test PC with the CPU installed. These tests reveal a broad range of performance characteristics, from image editing to gaming and video encoding to 3D rendering. We run all tests at stock speed and again when overclocked to its highest frequency.

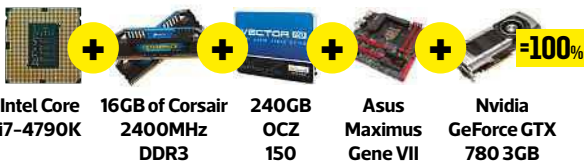
GRAPHICS CARDS

Graphics cards are mainly evaluated on how fast they are for their price. However, we also consider the efficacy and quietness of the cooler. Every graphics card is tested in the same PC, so all results are directly comparable.



CUSTOM PC REALBENCH 2015

INTEL REFERENCE



AMD REFERENCE

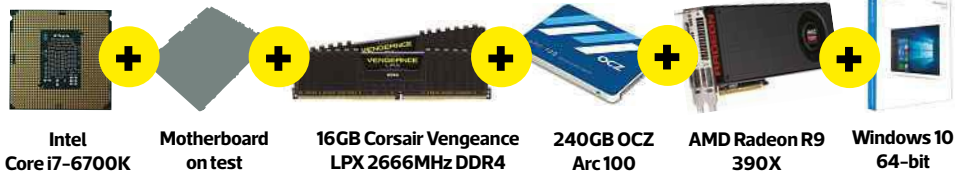


Our benchmark suite, co-developed with Asus, simulates how people really use PCs – a higher score is better. You can download them from www.asus.com/campaign/Realbench

MOTHERBOARDS

Motherboards are evaluated on everything from layout and features to overclockability and value for money. Every motherboard is tested with the same components, so all results are directly comparable.

INTEL LGA1151



INTEL LGA2011-V3



TESTS: We use Custom PC RealBench 2015 and Total War: Warhammer, and also test the speeds of the board's SATA and M.2 ports. We try to overclock every motherboard we review by testing for a maximum base clock as well as overclocking the CPU to its maximum air-cooled level. We run our tests at stock speed and with the CPU overclocked.

The Awards



EXTREME ULTRA

Some products are gloriously over the top. These items of excellent overkill earn our Extreme Ultra award.



PREMIUM GRADE

Premium Grade products are utterly desirable – we'd eat nothing but beans until we could afford them.



PROFESSIONAL

Products worthy of the Professional award make you and your business appear even more awesome.



APPROVED

Approved products are those that do a great job for the money; they're the canny purchase for a great PC.



CUSTOM KIT

For those gadgets and gizmos that really impress us, or that we can't live without, there's the Custom Kit award.



TESTS: By using the fast PC detailed on the left, we can be sure that any limitations are due to the graphics card on test, rather than being CPU limited. We test Deus Ex: Mankind Divided, Doom, Crysis 3, Fallout 4 and The Witcher 3: Wild Hunt at their maximum detail settings, in their highest DirectX mode, at several resolutions. High-end cards should be able to sustain playable frame rates at 2,560 x 1,440, while 1,920 x 1,080 is more important for mid-range cards; we also test at 3,840 x 2,160 for 4K monitors, and try to overclock every graphics card we test to assess the performance impact.



LABS TEST

House of cards

We've seen a flurry of activity in the sub-£250 GPU market recently, with AMD and Nvidia both releasing new cards. Ben Hardwidge pits them against each other in a variety of tests to see which cards offer the best bang per buck

Nvidia's flagship Titan X and GTX 1080 cards might be good for grabbing headlines and showing off, but only a handful of gamers can afford the large sums of money demanded by these top-end cards. Most graphics cards are sold in the sub-£250 portion, and the battleground in this sector is really hotting up. Not only has AMD released several brand-new GPUs in this price league, but Nvidia has also now brought its Pascal architecture into play with its GeForce GTX 1060 6GB and 3GB cards.

There's a lot of very new competition, and we've only been able to look at a couple of the options so far, so this month we've decided to take a look at all the new sub-£250 options, including various memory configurations, to see what you need to play games at 1,920 x 1,080 and 2,560 x 1,440.

Along the way, we'll also analyse how much graphics card memory you really need, and take a look at what's on offer if you drop right down to the £100 mark too.

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AMD Radeon RX480 8GB /p48

How much VRAM do you need? /p50

Nvidia GeForce GTX 1060 6GB /p51

Results graphs /page 52

How we test

We've recently updated our graphics test rig, which is now a high-end Skylake PC with an Asus Maximus VIII Hero motherboard and an Intel Core i5-6600K running at 4.4GHz. Alongside these components is 16GB (2 x 8GB) of Corsair Vengeance LED 3000MHz DDR4 RAM and a 480GB SanDisk Extreme Pro SSD. We use Windows 10 64-bit, and this month we've used the AMD Crimson driver 16.9.1 and the Nvidia GeForce driver 372.70.

We've tested each card in five separate games. *Crisis 3* is tested at Very High settings using a custom, 60-second macro-recorded play-through from the single-player mission Red Star Rising and, for *The Witcher III: Wild Hunt*, we record a 45-second manual play-through of Geralt entering and passing through a village on horseback at Very High settings with Nvidia HairWorks disabled.

Meanwhile, our *Fallout 4* test uses a 30-second manual play-through at Ultra settings with TAA enabled. We also test *Doom* using a 60-second manual play-through at Ultra settings in the UAC level.

This month also sees us introducing a new benchmark using the latest *Deus Ex* game, *Mankind Divided* (see p78). We use the game's built-in benchmark at Very High settings, timing 90 seconds of the benchmark. We record every test using



Our new graphics test rig features an Asus Maximus VIII Hero motherboard, a Skylake CPU overclocked to 4.4GHz and 16GB of Corsair Vengeance LED 3000MHz DDR4

the freely available FRAPS tool to ensure accuracy, and each test is performed three times for consistency.

Scoring standards

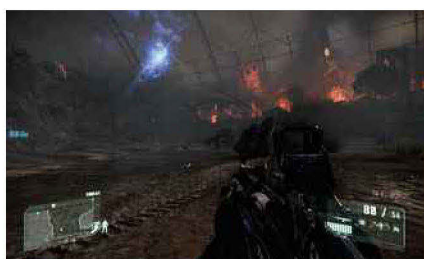
We've adopted a weighted scoring system for GPU group tests that's designed to highlight meaningful and real-world performance differences. The Performance component of the final scores is calculated through a point-based system, with points allocated based on the minimum frame rate achieved in each test.

We focus on minimum frame rates, as it's this performance that you'll really notice when your games slow down.

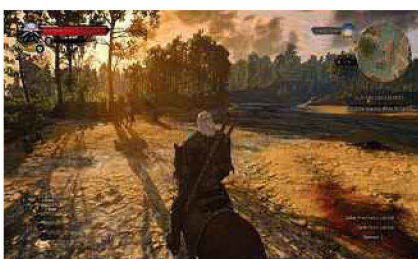
A result of between 25fps and 29fps, which we've consistently considered to be borderline playable, receives just one point. We consider 30fps to be the true minimum target for games to remain smooth and playable. As such, a minimum of 30fps or more is worth three points. If a minimum result exceeds 45fps, we award an extra half-point, as the game will feel a little smoother than at 30fps. It also means a card has more headroom for future titles and will be capable of hitting 60fps with fewer sacrifices to details. Lastly, any card whose minimum is above 60fps is awarded the full four points for that test. With the raw scores tallied up, our Excel spreadsheet weighs the cards against each other to calculate a Performance percentage for each resolution – each resolution is worth 30 per cent of the final score.

The Value score (30 per cent) is then calculated by dividing the total performance points by the cheapest available model of a given card at the time of writing. The final 10 per cent comes from the Efficiency score, which is based on how well a card performs across the tests compared with its peak power consumption under load (measured using Unigine Valley). We also report the idle power consumption for each card, and all power consumption results are for the whole system, not just the graphics card.

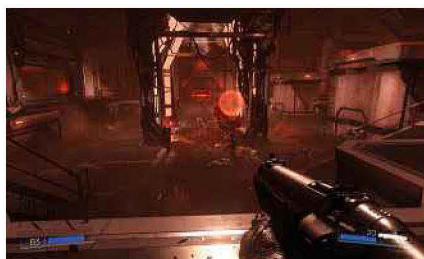
Our complex scoring method is designed to put the onus on real, useful performance in the current generation of games, with a scientific calculation used to tell us exactly which cards offer the best bang per buck, eliminating any potential prejudices.



Crisis 3 is tested using a custom, 60-second macro-recorded play-through



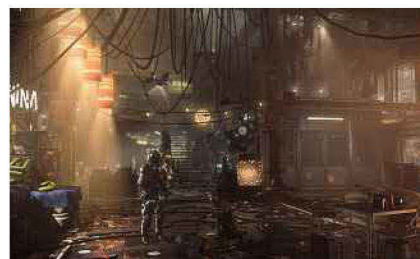
For *The Witcher III: Wild Hunt*, we record a 45-second manual play-through on horseback



Our *Doom* benchmark uses a 60-second manual play-through at Ultra settings in the UAC level



Our *Fallout 4* test uses a 30-second manual play-through at Ultra settings with TAA enabled



This month sees us introducing a new *Deus Ex: Mankind Divided* benchmark



AMD Radeon RX470 4GB / **£170** incVAT

SUPPLIER www.scan.co.uk / **CARD TESTED** Asus Strix Gaming Radeon RX470 (£189 inc VAT from www.scan.co.uk)

Asus' Strix Gaming Radeon RX470 wowed us last month, offering decent 1080p and 2,560 x 1,440 performance for under £200, all in a quiet, overclocked and good-looking package. At its stock speed, AMD's RX470 has a 926MHz base clock and a 1206MHz boost clock, but it's possible to get an overclocked card for not much more money than the reference spec.

The GPU itself is based on the same Polaris architecture found in AMD's pricier Radeon RX480 cards (see opposite), but with a slightly cut-down specification. The RX470 has 32 compute units, compared to the 36 compute units in the RX480, giving it a total of 2,048 stream processors and 128 texture units, although it has the same count of 32 ROPS found in the Radeon RX480.

You also get 4GB of GDDR5 memory running at 1650MHz (6600MHz effective), which is a fair bit slower than the 2000MHz (8GHz effective) frequency of the RX480's memory. On the plus side, it's attached to a 256-bit wide memory interface, giving you a total memory bandwidth of 211GB/sec.

Performance

Despite being the cheapest card on test, the RX470 managed to stay above 30fps in all our game tests at 1080p, including the challenging Deus Ex: Mankind Divided, where it still produced a solid minimum of 34fps. It wasn't quite quick enough to hit the golden 60fps minimum in any of our tests, but its

gameplay at 1080p is still smooth – it never dropped below 50fps in Doom, The Witcher 3 or Crysis 3, and its 41fps minimum in Fallout 4 is a decent result at Ultra settings too.

The RX470 can also handle some gaming at 2,560 x 1,440, never dropping below 30fps in Crysis 3, Doom or The Witcher 3. However, its 25fps minimum in Fallout 4 is only borderline playable – we recommend running this game at High settings, rather than Ultra, on this card. Its 23fps minimum in Deus Ex: Mankind Divided at this resolution is also unplayable, although to be fair, none of the cards on test managed to hit a 30fps minimum in this test.

The problem for the RX470 now, though, is that you can pick up 3GB GeForce GTX 1060 cards for just £10 more, and they offer a significant jump in performance, particularly if you want to play games at 2,560 x 1,440. The GTX 1060 3GB beats the RX470 in every single one of our game tests, often by a substantial margin.

Meanwhile, one interesting area for the AMD cards this month was power consumption. We measured the idle power consumption of our system with the RX470 installed at 90W, which is fine, being only 5W higher than with the Nvidia GPUs on test. For the most part, the power consumption at load was fine too, with our system generally drawing around 250W at peak. However, in the third run of Unigine Valley, our test rig's power consumption started to spike higher

when any of the AMD cards were installed, hitting 293W with the RX470. This result isn't a huge worry; we only saw these power spikes very occasionally, and the result isn't terrible either way, but the Nvidia cards clearly have the edge in terms of efficiency at the moment.

Conclusion

AMD's Radeon RX470 can handle 1080p gaming fine, and it can manage some solid frame rates at 2,560 x 1,440 too. However, Nvidia's 3GB GeForce GTX 1060 has smacked it down to earth with a bang, costing just £15 more, but offering substantially faster frame rates while consuming less power.

The Radeon RX470 now costs too much money for the performance it offers, but that's not to say it's a bad GPU. If you've already bought a Radeon RX470 card, it will continue to offer decent gaming performance, but the 3GB GTX 1060 now offers a better deal in this price league.

1920 SPEED 26/30	2560 SPEED 20/30	OVERALL SCORE 79%
EFFICIENCY 7/10	VALUE 26/30	

VERDICT

Decent frame rates from the cheapest card on test, but Nvidia's 3GB GeForce GTX 1060 offers substantially quicker performance for just £15 more.



Nvidia GeForce GTX 1060 3GB / **£185** inc VAT

SUPPLIER www.overclockers.co.uk / **CARD TESTED** MSI GeForce GTX 1060 Gaming X 3GB (£228 inc VAT from www.overclockers.co.uk)

Showing that you can't necessarily judge a graphics card on how much memory is soldered to its PCB, Nvidia's cheaper GeForce GTX 1060 cards include just 3GB of memory, yet cost more money than AMD's 4GB Radeon RX470 cards. We've taken a proper look at the impact of graphics memory on p50, and there are some instances where our tests go over the 3GB mark, but the underlying GPU here is so powerful that the limited amount of memory rarely has a significant impact on performance.

The memory isn't the only difference between the GeForce GTX 1060 3GB and its 6GB bigger sibling either; the 3GB cards also have a slightly cut-down GPU, featuring 1,152 stream processors compared to the 1,280 stream processors in GeForce GTX 1060 6GB GPUs. It's otherwise the same stock spec, though, with a 1506MHz base clock speed that boosts to up to 1708MHz, an 8GHz (effective) GDDR5 memory frequency and a 192-bit wide memory interface.

The upshot of this cheaper card, though, is that you can now get your hands on a proper piece of Pascal silicon for under £200, with Overclockers offering a Value 'Reference Design' edition for just £185 inc VAT.

Performance

Despite having fewer stream processors and less memory than its 6GB counterpart, the GeForce GTX 1060 3GB was only slightly behind the former in our tests. Perhaps more

importantly, though, it stayed ahead of the pricier AMD Radeon RX480 cards in most of our tests. A notable exception is Deus Ex: Mankind Divided (an AMD Gaming Evolved title), where it failed to achieve a borderline playable frame rate at 2,560 x 1,440.

In almost every other test, though, the 3GB GeForce GTX 1060 storms ahead, with amazing results in Doom. It even maintained a minimum of 32fps in Fallout 4 at 2,560 x 1,440 with Ultra settings. The RX480 cards were slightly quicker in The Witcher 3 at 2,560 x 1,440, but the GTX 1060 3GB has enough headroom here to enable features such as Nvidia HairWorks, which will significantly lower performance on the AMD GPUs.

Perhaps the only issue for the GeForce GTX 1060 3GB is its comparatively lowly memory allocation, as it struggles when the memory is really loaded. In Deus Ex: Mankind Divided at Ultra settings, for example, the 3GB card only manages a borderline playable minimum frame rate of 25fps at 1080p, while the 6GB Radeon RX480 goes up to 35fps.

Where this card really impresses, though, is in power efficiency. Our test rig only peaked at 243W with the GTX 1060 3GB installed at full load, demonstrating fantastic performance per watt – even if you ignore the results from the AMD GPUs' occasional power spikes, and take the general result, the GTX 1060 3GB still consumes less power and produces generally faster frame rates.

Conclusion

With fantastic frame rates, amazingly low power consumption and a surprisingly low price, Nvidia's GeForce GTX 1060 3GB hits the clear sweet spot in terms of bang per buck and performance per watt. In fact, even if you swap the price in our scientific spreadsheet for the £228 price of the overclocked MSI GeForce GTX 1060 Gaming X 3GB card we tested, which is quiet and well designed, its overall score still comes out 3 per cent above the reference AMD Radeon RX480 4GB.

The only concern is whether future titles will push it to its limit in terms of memory demands, which is already demonstrated in Deus Ex: Mankind Divided at Ultra settings, although it will only be an issue in very demanding games at very high settings. If that's a worry, then the 6GB version (see p51) has you covered, but at a price of just £185, the GeForce GTX 1060 3GB offers amazing performance in current games for the money.

1920 SPEED 30/30	2560 SPEED 25/30	OVERALL SCORE 93%
EFFICIENCY 10/10	VALUE 28/30	
VERDICT		

VERDICT

Incredible performance and efficiency for the money, despite its cut-down spec. It struggles in Deus Ex at Ultra settings, but it's a clear winner in terms of bang per buck.



AMD Radeon RX480 4GB / £195 inc VAT

SUPPLIER www.ebuyer.com / CARD TESTED AMD reference card

The 4GB AMD Radeon RX480 cards enable you to get a piece of Polaris action for just under £200, which still gets you access to a full fat 14nm Polaris GPU. Unlike the 3GB GeForce GTX 1060, the 4GB AMD Radeon RX480 doesn't have a cut-down GPU – every part of its Polaris chip is enabled and fully functional, giving you nine compute units, each of which contains 64 stream processors for a total of 2,304.

By default, the GPU has a 1120MHz base clock, boosting to 1266MHz, and this spec is the same between both the 4GB and 8GB cards. However, there's one small difference between the 4GB and 8GB cards, aside from the amount of memory, which is the GDDR5 memory clock – the 4GB cards have a stock memory speed of 1750MHz (7GHz effective), while the 8GB cards run the memory at 2000MHz (8GHz effective).

Performance

With a full-spec GPU and just a slight drop in memory frequency, for the most part, the AMD Radeon RX480 4GB was only just behind its 8GB sibling, offering decent speeds. The 4GB card never dropped below 60fps in Doom or The Witcher 3: Wild Hunt, and its 59fps minimum in Crysis 3 is very close to hitting the 60fps golden target too. Its 39fps minimum in Deus Ex: Mankind Divided at Very High settings is also praiseworthy.

The 4GB Radeon RX480 also held its head high in our 2,560 x 1,440 tests, managing playable frame rates in all our standard test

games, including a borderline playable result in Deus Ex: Mankind Divided. However, it notably falls behind Nvidia's cheaper GeForce GTX 1060 3GB in a number of tests. The Nvidia GPU's 32fps minimum in Fallout 4 at 2,560 x 1,440 with Ultra settings, for example, beats the 4GB RX480's 28fps, and the former's results in Doom and Crysis 3 are also well in front of the AMD card.

On the plus side, though, the extra 1GB of memory gives the 4GB RX480 a decent benefit in Deus Ex: Mankind Divided at Ultra settings, where its 30fps minimum at 1080p beats the GTX 1060 3GB's 25fps. Overall, though, the 3GB GTX 1060 is significantly quicker than the 4GB RX480 across most of our tests, and it's more power-efficient too.

As with the RX470 (see p42), the 4GB RX480's power consumption occasionally spiked in the third run of our Unigine Valley test, with our test rig peaking at 319W. In the previous two runs, the system drew a peak of just 287W, which is a decent result, although a fair bit higher than the 243W with the 3GB GTX 1060 installed. AMD's Polaris architecture definitely improves power efficiency over the company's last-generation GPUs, but it can't beat the performance per watt of Pascal.

Conclusion

The 4GB version of the RX480 brings the price of AMD's full fat Polaris GPU below the £200 barrier, and the lower memory allocation only really impacts performance in Deus Ex: Mankind Divided at Ultra settings, which is very

demanding on graphics memory. In terms of bang per buck, the 4GB RX480 is undoubtedly the most competitive offering from AMD at the moment.

However, even at £195, the RX480 really struggles to compete with the £185 3GB GeForce GTX 1060. The latter significantly outperforms the 4GB RX480 in nearly every one of our game tests – it's only in Deus Ex where the RX480 can noticeably pull away. The AMD card's power consumption is also significantly higher, even if you ignore the occasional power spikes, showing that Nvidia's Pascal architecture beats Polaris in terms of performance per watt as well as bang per buck.

There are still reasons to consider an RX480 card over a GTX 1060, such as water-cooling support and their generally smaller PCBs. However, in a straight contest for bang per buck and performance per watt, the 4GB Radeon RX480 is firmly beaten by Nvidia's 3GB GeForce GTX 1060.

1920 SPEED 29/30	2560 SPEED 23/30	OVERALL SCORE 84%
EFFICIENCY 7/10	VALUE 25/30	

VERDICT

The most competitive AMD offering, with decent performance at 1080p and 2,560 x 1,440, but at this price, it can't compete with the cheaper GeForce GTX 1060 3GB.



Aluminum PC Case



PC-09 WX

Tempered Glass Panel

PC-09 WRX / PC-09 WX

Drive Bays: 3.5" HDD x 6, 2.5" HDD x 2
Expansion Slots: 8
M/B Type: ATX, Micro-ATX, E-ATX (322 x 272 mm)
Fans: 120 mm x 5
I/O Ports: USB 3.0 x 4 (20 pin-plug) / HD Audio
LED RGB Color Changing Kit: (LED50RGB-2) x 1
Dim.: (W)354 x (H)482 x (D)465 mm

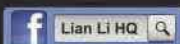


PC-09 WRX



PC-Y6 W 2016 SPECIAL EDITION

Distributor



www.lian-li.com Welcome OEM / ODM Project

Cheaper GPUs

You can get a new AMD Polaris GPU for just £100, but do you lose much performance in the process? We try out a Radeon RX460 card to find out

Although this Labs test is focused on cards costing under £250, the cards on test sit at the upper end of that scale. We've previously found that GPU performance falls off a cliff once you get below a certain price, where graphics cards become bottlenecked by narrow memory interfaces, slower clock speeds and fewer stream processors. But is this still the case? AMD's new Polaris-based Radeon RX460 is available in both 2GB and 4GB versions, with prices circulating the £100 mark. Can you really get respectable performance for this money? To help us find out, AMD sent us a Gigabyte WindForce 2 RX460 2GB card (£113 from www.scan.co.uk).

The RX460 is built with the same 14nm FinFET transistors found in its bigger siblings, and its low power requirements mean it doesn't need a PCI-E power connector – it can draw all its power from the PCI-E slot. The GPU itself features 14 compute units, giving you a total of 896 stream processors, and the reference spec has a 1090MHz base clock with a 1200MHz boost clock. Meanwhile, the GDDR5 memory is clocked at 1750MHz (~7GHz effective), and it's attached to a 128-bit wide memory interface, giving you a total memory bandwidth of 112GB/sec – a big drop from the Radeon RX470's 211GB/sec.

We had to set some realistic goals before testing the RX460. It clearly isn't built for 2,560 x 1,440 gaming and, as a result, we felt it was unfair to include it in our scoring system, so we could instead focus on 1,920 x 1,080 performance. Sadly, though, our standard 1080p gaming benchmarks were still too much for the RX460 – it dropped below 30fps in all of our tests, and only achieved borderline playable frame rates in Crysis 3 and The Witcher 3.

We then dropped the detail preset by one notch on each of game, and the RX460 stayed above 30fps in Crysis 3 and The Witcher 3: Wild Hunt, and nearly hit the 30fps minimum target in Fallout 4.

All the games still look good at these settings too. However, Doom and Deus Ex: Mankind Divided were still juddery at these lower settings.

Conclusion

To be fair to AMD, the Radeon RX460 isn't designed to play the most demanding games at high settings. It's aimed at mainstream established games, such as League of Legends and DOTA 2, played at 1080p. If that's all you want to play, and you want a step up from integrated graphics, the RX460 will likely do it, and also give you a shot at Fallout 4 and The Witcher 3 if you

drop the settings. What's striking, though, is the gulf between the RX460's frame rates and those of AMD's next GPU up, the RX470.

Radeon RX460 2GB cards might be temptingly cheap, but the Radeon RX470 and GeForce GTX 1060 3GB both offer much better value in terms of bang per buck if you want to play demanding games. Even if you have a limited budget, we advise avoiding the RX460 and saving a little more money to enter the next league of GPUs, as the performance benefits are massive.



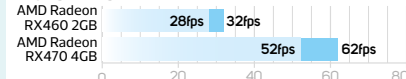
This Gigabyte WindForce 2 Radeon RX460 2GB card gets all its power from your PCI-E 3 slot

CRYSIS 3

1,920 x 1,080, High settings, 0x AA

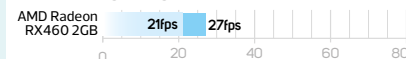


Very High settings, 0x AA

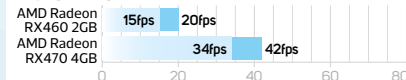


DEUS EX: MANKIND DIVIDED

1,920 x 1,080, High settings

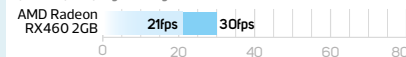


Very high settings

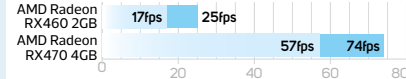


DOOM

1,920 x 1,080, High settings

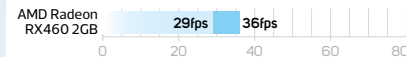


Ultra settings

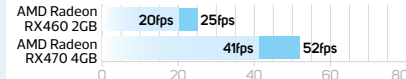


FALLOUT 4

1,920 x 1,080, High settings

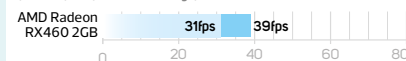


Ultra settings

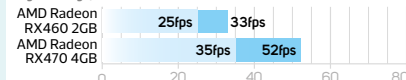


THE WITCHER 3: WILD HUNT

1,920 x 1,080, Medium settings, Nvidia HairWorks off



High settings, Nvidia Hairworks off



Minimum Average

iiyama G-MASTER™ MONITORS 4 GAMERS

RED EAGLE™

GB2488HSU | GB2788HS

Panel	LED 1920 x 1080
Response time	1 ms, 144Hz, FreeSync™
Features	OverDrive, Black Tuner, Blue Light Reducer, Predefined and Custom Gaming Modes
Inputs	DisplayPort, HDMI, DVI
Audio	speakers and headphone connector
Height adjustment	13 cm

24"

27"

144Hz

Free Sync



gmaster.iiyama.com



AMD Radeon RX480 8GB / £227 inc VAT

SUPPLIER www.ebuyer.com / CARD TESTED AMD reference card

The 8GB flavour of AMD's Radeon RX480, provided our first glimpse of AMD's new 14nm FinFET line-up back in Issue 156. It impressed us by nearly matching the performance of Nvidia's GeForce GTX 970 while still only costing £219 inc VAT and massively improving on AMD's previously woeful power efficiency. But a lot has changed in just three months, with fluctuating prices after the referendum, and Nvidia's new GeForce GTX 1060 cards shaking up the market.

If you look around, you can find 8GB RX480 cards with prices that now aren't far off the launch price, but is that enough to fend off Nvidia's aggression? Unlike Nvidia's two GTX 1060 versions, there's little difference between the 4GB RX480 and the 8GB model. Both GPUs have the same nine compute units, giving you a total of 2,304 stream processors, and the same GPU clock speed of 1120MHz (1266MHz boost). The only difference is a slight change in the GDDR5 memory clock, from 1750MHz (7GHz effective) on the 4GB cards to 2000MHz (8GHz effective) on the 8GB cards.

Performance

Let's start with the good news, which is that if you want to play games at 1080p, the RX480 is a storming card, getting full marks in this section and never dropping below 60fps in The Witcher 3, Doom or Crysis 3. It also tops the chart on the Deus Ex: Mankind Divided

benchmark, with a decent minimum of 41fps. Its extra memory also gives it a helping hand in this game at Ultra settings, where its 35fps minimum is the best result on test.

However, there's no getting away from the fact that the GeForce GTX 1060 6GB beats it in every other test, often by a fair margin – you'll notice the difference between the RX480's 29fps minimum in Fallout 4 at 2,560 x 1,440 and the GeForce GTX 1060 6GB's 32fps result. Also, the 6GB GTX 1069 never dropped below 60fps in Doom at 2,560 x 1,440 with Ultra settings, while the RX480 was dropping to 47fps – the latter is still a decent result, but it needs to be faster when competition is this tight. It also doesn't help that, in many of our tests, the 3GB GTX 1060 also outperforms the RX480 8GB, despite its much lower price.

Where the RX480 has the upper hand, of course, is by having the most video memory of the cards on test, although our testing on p50 shows that 6GB will be more than enough for gaming at 2,560 x 1,440, and that you can get away with less memory for the most part. The RX480's memory may have helped it to get the best result in Deus Ex: Mankind Divided at Ultra settings at 2,560 x 1,440, but the 24fps minimum is still unplayable, rendering the extra power moot.

Also, as with the other AMD GPUs on test, our test system's power consumption started to spike in the third run of our Unigine Valley test with the 8GB RX480 installed. We recorded a peak draw of 323W with the

RX480 in our test rig, which is the highest result on test. It only occasionally spiked to these levels, with the power consumption generally peaking at around 290W, but even this result is a fair bit higher than the 258W peak draw of the GTX 1060 6GB, which is also generally quicker.

Conclusion

AMD's Radeon RX480 8GB has survived the storms without getting wrecked on the beach – it's still a decent card, and if you've already bought one you'll get plenty of joy out of it yet. There are also some areas where it has the upper hand, such as Deus Ex: Mankind Divided.

However, in every other test, the RX480 8GB is beaten by Nvidia's aggressive GeForce GTX 1060 6GB, which also consumes less power at peak load and only costs an extra £12. At its current price, the RX480 8GB simply can't compete any more.

1920 SPEED 30/30	2560 SPEED 23/30	OVERALL SCORE 82%
EFFICIENCY 7/10	VALUE 22/30	

VERDICT

Still a decent card, offering solid frame rates at 1080p and 2,560 x 1,440, but its performance, efficiency and value are now firmly beaten by Nvidia's GTX 1060.

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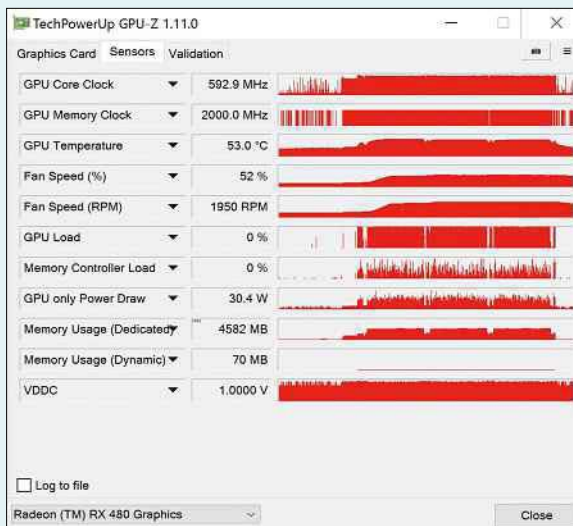
How much VRAM do you need?

When it comes to VRAM, more is better, right? After all, if your graphics card has more video memory (VRAM), then it has more room to store all your games' graphical goodness in high-speed chips, resulting in faster performance. But will your card actually use that extra memory? We decided to find out by monitoring VRAM usage on our standard graphics test rig (see p41) with an AMD Radeon RX480 8GB card, using GPU-Z (www.techpowerup.com/gpuz) to monitor peak VRAM use over three runs of each of our benchmarks.

Two surprises were that both The Witcher 3 at High settings and Crysis 3 at Very High settings didn't even break the 2GB mark at 1080p, and only used slightly more than 2GB at 2,560 x 1,440. Fallout 4 sat below the 3GB mark too, even at Ultra settings at 2,560 x 1,440.

Where VRAM use hit the bigger numbers was in our two newest tests, Doom and Deus Ex: Mankind Divided. Even at 1080p, our Doom benchmark broke the 3GB barrier, climbing to 3,608MB at 2,560 x 1,440. However, that doesn't necessarily mean you need 3GB of VRAM in order to play Doom at Ultra settings.

It just means that having more memory may give you a little more speed, as your card won't be bottlenecked. The GeForce GTX 1080 3GB manages to play Doom at 2,560 x 1,440 without dropping below 56fps, while the 6GB card hits the 60fps



We monitored each of our game tests using GPU-Z, pictured here after running Deus Ex at Ultra settings

target. There's a benefit to more memory, but in this case it's small.

The big memory hog is Deus Ex: Mankind Divided, which peaked at 3,798MB at 2,560 x 1,440 with Very High settings. In this test, the 4GB RX480 has the edge over the 3GB GTX 1060, although it's hard to say how much of this difference is down to the memory. Although our standard tests showed some games using more than 3GB of VRAM if it was available, a 3GB card could clearly cope with the workload. We needed a more challenging test, so we then ran Deus Ex: Mankind Divided at Ultra settings. Enabling this game's Ultra preset gives you

a warning that you need more than 4GB of video memory to perform well and, sure enough, we then broke the 4GB barrier, with VRAM use hitting 4,132MB at 1,920 x 1,080 and 4,582MB at 2,560 x 1,440.

You could see how the extra memory affected the GPUs' performance. At 1080p, the 8GB RX480 managed a respectably playable minimum of 35fps at

Ultra settings, while the GeForce GTX 1060 3GB could only manage 25fps – a much larger performance difference than at Very High settings.

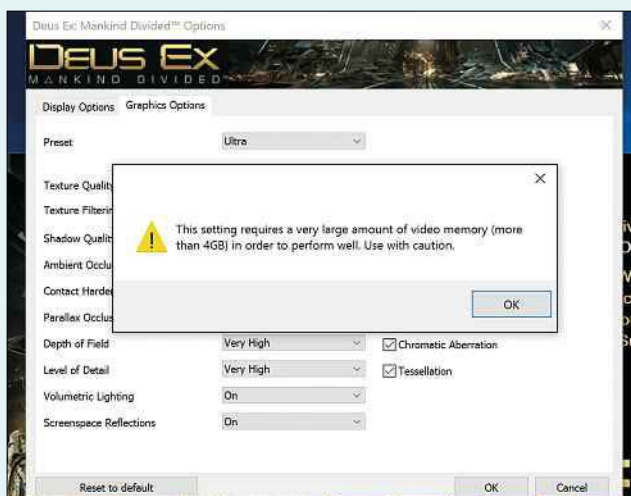
The difference was stark at 2,560 x 1,440 too, although none of these frame rates was playable at these settings.

Conclusion

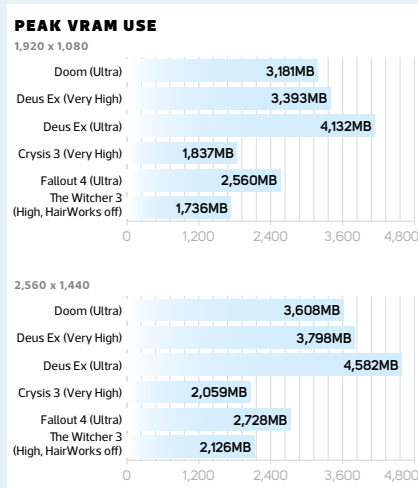
While you don't need more than 4GB of VRAM on a mid-range card for the most part, the margins are closer than you might imagine. Several current games use more than 3GB

of VRAM, even at 1,920 x 1,080, and while the 3GB GTX 1060 still performs great in most of these games, future games might be more demanding. The 8GB RX480 also has a serious performance benefit over the 3GB GTX 1060 in Deus Ex: Mankind Divided, with a 10fps difference between the minimum frame rates at Ultra settings.

You have to really push a demanding game to its limit to see these results though. If you can't afford a 6GB or 8GB card, the 3GB GTX 1060 is still very capable – you just might not be able to run some future games at Ultra settings. For future proofing, though, and for Deus Ex: Mankind Divided, if you have the money we recommend spending a little bit more money on a 6GB or 8GB card.



Deus Ex: Mankind Divided throws up a dialogue box telling you that you'll need more than 4GB of VRAM to get good performance at Ultra settings





Nvidia GeForce GTX 1060 6GB / £239 inc VAT

SUPPLIER www.scan.co.uk / **CARD TESTED** Zotac GeForce GTX 1060 AMP! Edition 6GB (£264 inc VAT from www.scan.co.uk)

Sitting just shy of the £250 price limit of this month's Labs test is Nvidia's full-fat GeForce GTX 1060 6GB, which not only features twice as much GDDR5 memory as its 3GB little siblings, but also has a slightly beefier GPU. The 6GB flavour of the GTX 1060 has 1,280 stream processors, compared to 1,152 in the cheaper model. The 6GB cards also demanding £54 more than the 3GB versions.

The two flavours otherwise share the same spec, though, with a stock GPU clocked at 1506MHz and boosting to 1708MHz, although the latter figure is a little conservative. Our Zotac sample happily boosted to 1898MHz during our benchmarks, even with the base clock running at stock frequency. Meanwhile, the 6GB of GDDR5 memory runs at 2002MHz (8GHz effective), and is attached to a 192-bit-wide memory interface.

Performance

As the priciest card on test, we expected some serious performance from the 6GB GTX 1060, and we weren't disappointed. Like the Radeon RX480 8GB, it achieved full marks in our 1080p tests, but it also excelled in our 2,560 x 1,440 tests. Most notably, it never dropped below 60fps in Doom at this resolution, even at Ultra settings, and its 34fps minimum in Fallout 4 at 2,560 x 1,440 with Ultra settings is also praiseworthy for a sub-£250 card. The 6GB card sits at the top of the leaderboard for

nearly every other game in this Labs test too, showing that it has some serious power.

The exception is Deus Ex: Mankind Divided, where AMD's RX480 has the edge, although that's no surprise given that it's an AMD Gaming Evolved title. The GTX 1060 6GB still holds its own in this game, though, achieving a solid minimum of 38fps at 1080p at Very High settings, and even staying above 30fps at Ultra settings, which is where it has the edge over its 3GB sibling. A large part of this performance advantage is undoubtedly down to the extra memory, which we've discussed on p50.

What's interesting, though, is that although the 6GB GTX 1060 is the quickest card on test overall, its 3GB sibling is generally only a short way behind, despite having a lesser GPU and half as much memory. Nvidia's Pascal architecture is clearly a formidable force, even when it's intentionally cut down. Power consumption is great too – the peak result of 258W from our system with the 6GB card installed is 15W higher than with the 3GB card installed, and is significantly lower than with the Radeon RX480 cards.

Conclusion

Nvidia's GeForce GTX 1060 6GB is the current sub-£250 king, managing comfortably playable frame rates in all our games at 1080p and most of our games at 2,560 x 1,440 – it only drops below 30fps at the latter resolution in Deus Ex: Mankind Divided, where the AMD

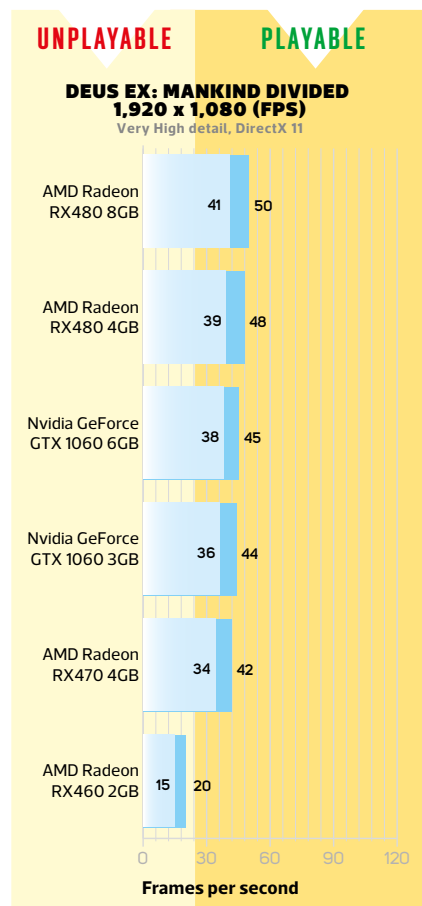
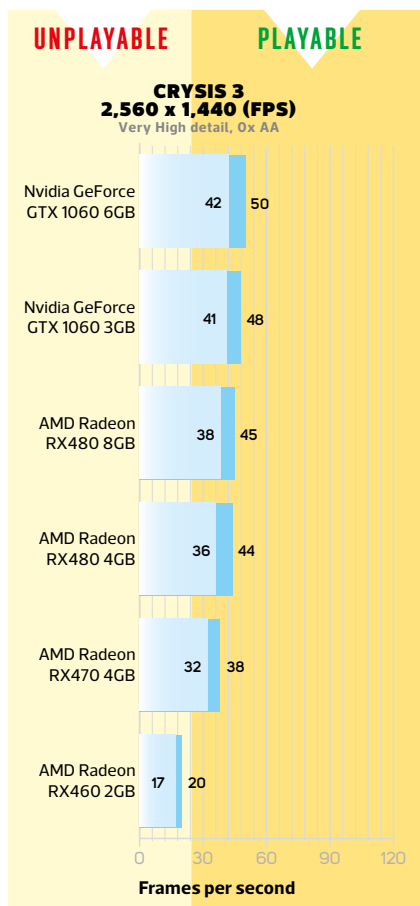
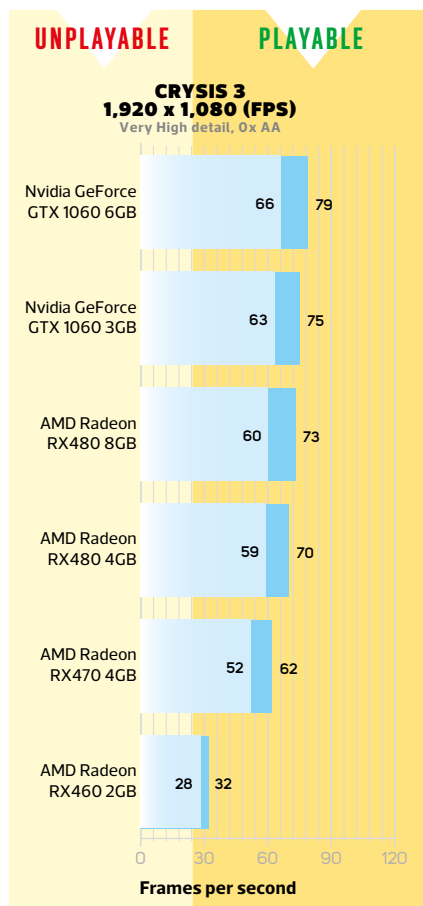
GPUs can also only manage borderline playable frame rates. The extra memory also gives the top-end GTX 1060 an edge over its 3GB counterpart in very demanding games, such as Deus Ex: Mankind Divided.

However, you pay a lot more money over the 3GB card for the extra memory and slightly higher number of stream processors, and while the 6GB card is quicker, its bang per buck is lower. If you can't afford the extra £54, the 3GB GTX 1060 will still serve you fine in most games at 1080p and 2,560 x 1,440. That said, there's no way for our scientific scoring system to account for future proofing, and if the demands of Deus Ex: Mankind Divided at Ultra settings are a yardstick for future games, that extra cash may be worth the investment in the future. If you want the best card in this league then the 6GB GTX 1060 is the one to buy, but if you're on a tight budget, the 3GB card arguably offers better value for money.

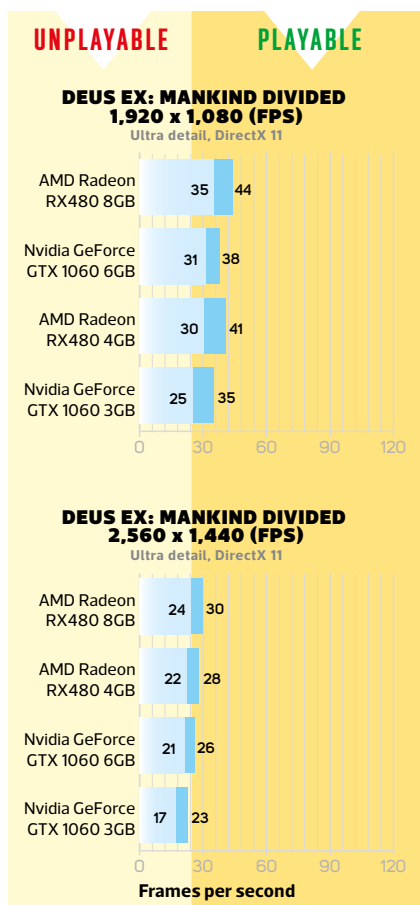
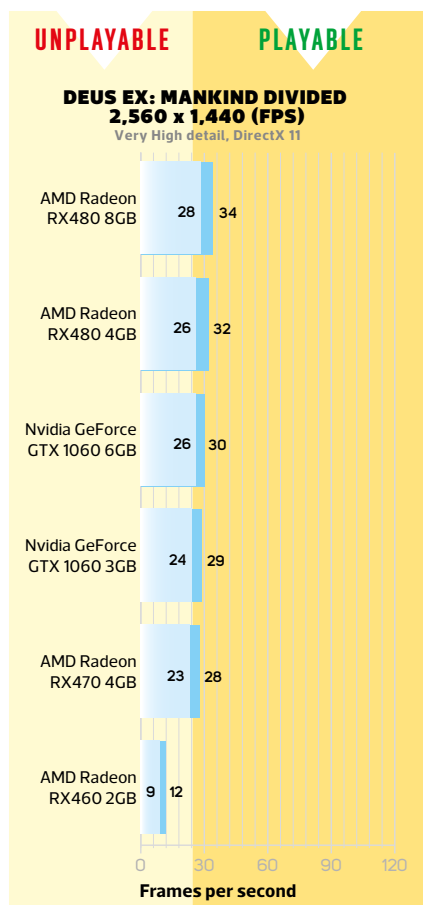
1920 SPEED 30/30	2560 SPEED 28/30	OVERALL SCORE 91%
EFFICIENCY 10/10	VALUE 23/30	

VERDICT

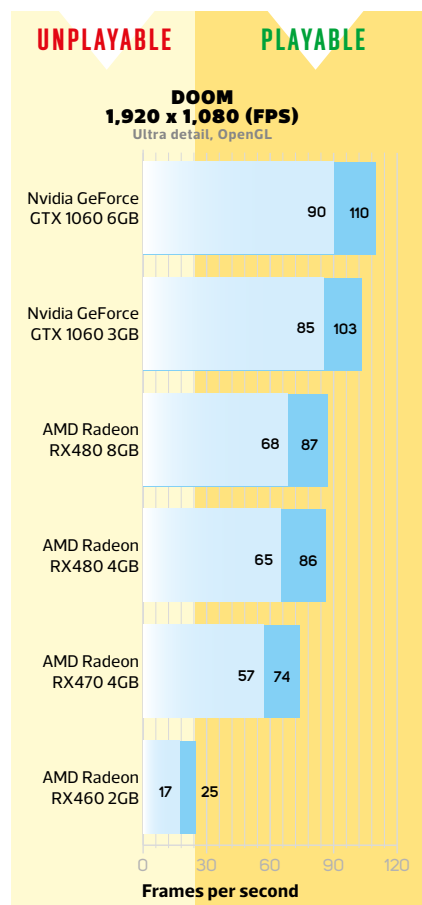
The king of sub-£250 graphics cards, with killer performance and efficiency, plus plenty of memory headroom, although its bang per buck is lower than its 3GB counterpart.

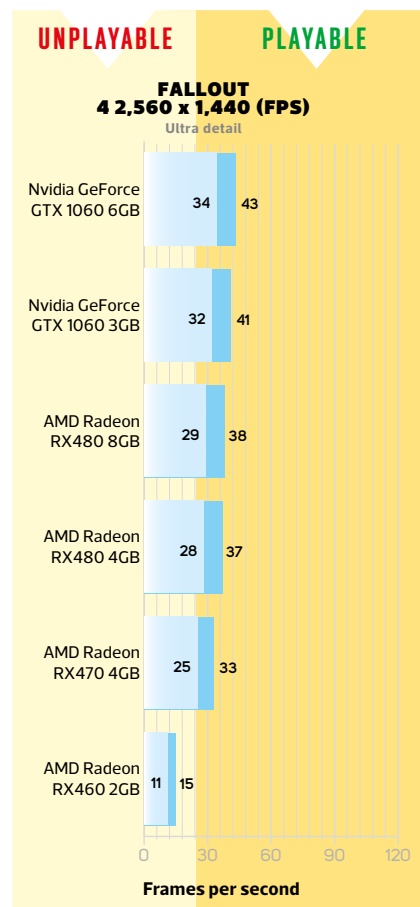
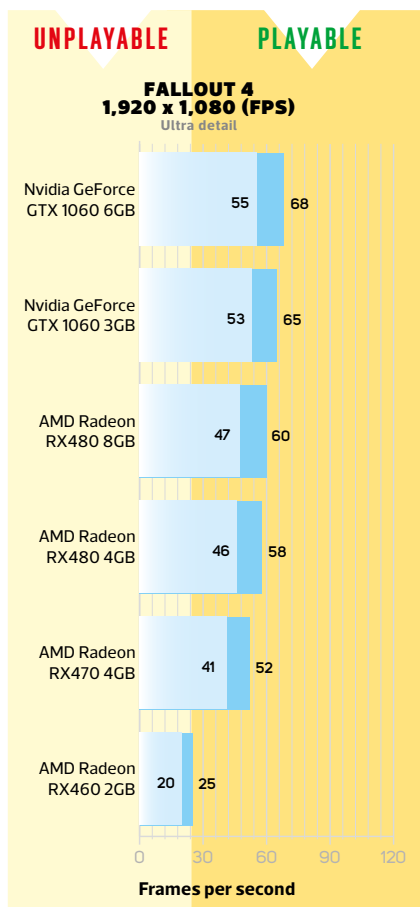
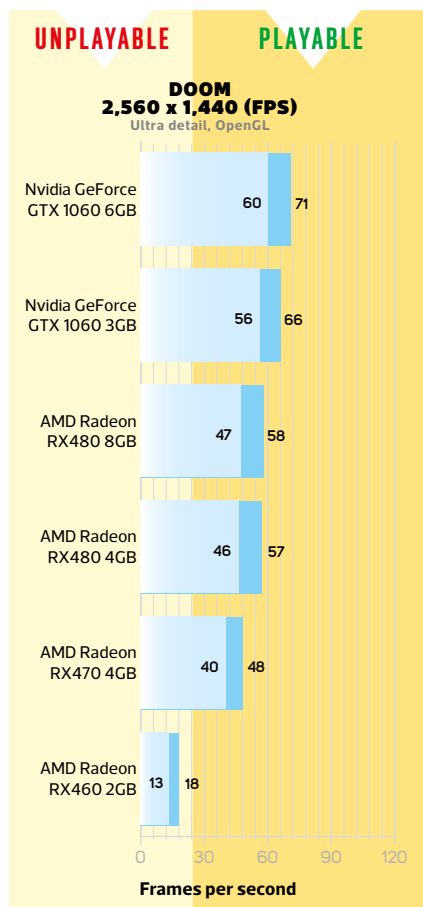


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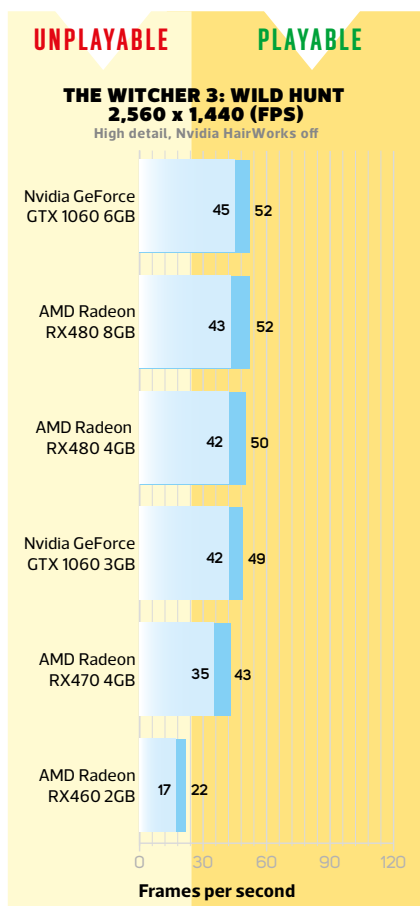
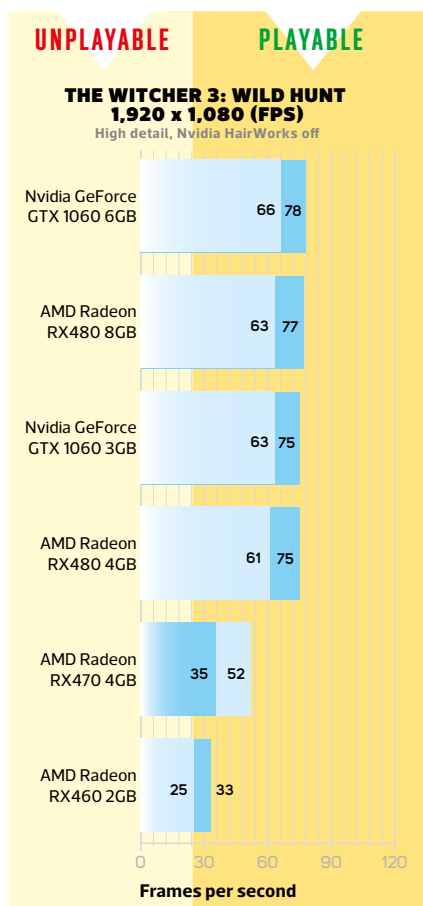


Minimum Average





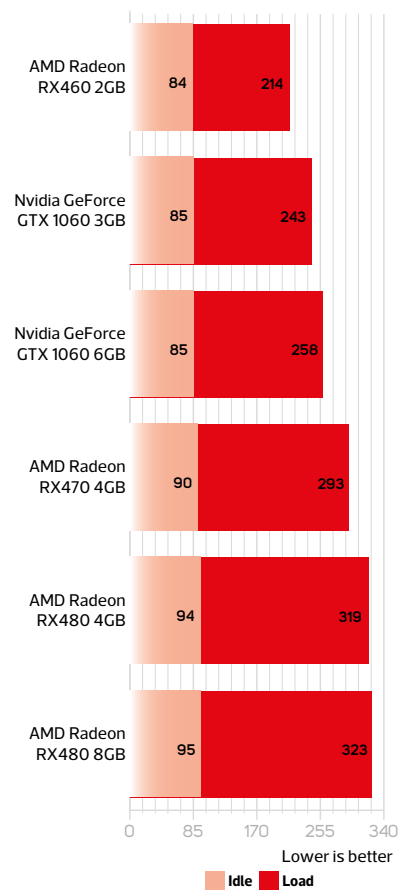
Minimum Average



Minimum Average

POWER CONSUMPTION (WATTS)

Windows Desktop / Unigine Valley





LABS TEST

Wheels of fortune

Antony Leather takes a look at the latest PC racing wheels, so he can steer your money in the right direction

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Serious sims / p57

Thrustmaster T300 RS / p58

Thrustmaster TMX Force Feedback / p59

How we test

Like joysticks, racing wheels can bridge the huge gap in realism between a game pad and actually driving a car. A good wheel will make you feel like you're really driving a vehicle, especially with the addition of force feedback, which has come a long way in the past few years.

Thankfully, PC gamers no longer have to tolerate dodgy software and drivers when using racing wheels on a PC either. The latest games and hardware usually pair up

perfectly for some excellent PC racing sessions, offering the next best experience to driving on a track with hundreds of horsepower. However, profiles, calibration and force feedback still differ a fair bit between racing wheels and, more importantly, the wheels themselves use all manner of ways to mount on your desk and offer a realistic driving experience.

We've pitted five sub-£250 racing wheel and pedal sets against the might of games such as *Dirt Rally* and *F1 2016* to

see which ones offer the most realistic experiences, and use their force feedback most effectively to make your arms feel like they've done 50 laps of Spa-Francorchamps.

We've also configured each wheel to assess their customisability and suitability for typical setup in an average bedroom with a desk. As the legendary Logitech G27 gradually fades from stock, which wheel will take up the mantle of the best affordable racing wheel?



Logitech G920 Driving Force / **£180** inc VAT

SUPPLIER www.currys.co.uk / MODEL NUMBER 941-000124

When it comes to competing for the best racing wheel title, Logitech has a particularly tough challenge because of the simple fact that its legendary G27 wheel set, while discontinued and very hard to find, is still considered the benchmark for premium racing wheels costing under £300. In the past year, Logitech has launched several new wheels, including the G920 Driving Force – a combined force feedback wheel and pedal set with flappy paddles – and initially it wasn't received particularly well.

The original price of £300 inc VAT saw it cost considerably more than the G27, and the G920 lacked a gearstick too – a feature that was included with the G27 as standard. Thankfully, Logitech has seen sense and in fewer than six months since the G920's launch last year, it's cut the price of the G920 to below £200, with a separate gearstick module now available for £45 too.

The G920 Driving Force is a beast of a racing wheel, with mains-powered, dual-motor force feedback and 900-degree steering rotation. The wheel is also completely covered in leather so it feels very realistic, although the rubber finish of the Thrustmaster T300RS has better grip.

Mounting the wheel section is achieved using two U-shaped clamps, which are secured by twisting dials on top of the unit. There's only 3cm of desk thickness clearance as standard, but we found that by prying off the caps on the tops of the clamps gave us a good 5cm with no difference to the stability

of the mount. However, the G920 doesn't give you as much padding as the Thrustmaster sets, so you'll need to be careful not to damage the surface of your desk or table.

The G920 Driving Force is compatible with the Xbox and PC, so not surprisingly, it's equipped with a D-pad and console-like buttons too, although these controls are also useful for assigning to driving functions such as the handbrake, views or even nitrous oxide

The wheel is completely covered in leather, so it feels very realistic

systems. Meanwhile, the paddle shifters are solid and very similar to the shifters we've felt on real cars – they're the most realistic-feeling paddle shifters on test.

When you start gaming, the G920 really feels fantastic, with very detailed force feedback, although some of the effects feel a little repetitive. The wheel is wonderfully responsive, as are the pedals, and the G920 is also the only set to include a clutch pedal, although you'll obviously need to invest in the optional gear shifter in order to use it. You can firmly plant the pedal base on the floor too, where it never moves as long as you rest your heels on the base.

There's a little too much force feedback applied as standard though. In *Dirt Rally*, for example, we found the need to tone down the tyre resistance, but the preset available for the G920 in the game was otherwise fine. The G920 was also great to use in *F1 2016*, despite the fact that this game hasn't been added to Logitech's software profile yet.

Conclusion

The Logitech G920 Driving Force now offers excellent value for money at a price of just £180 inc VAT, costing nearly £40 less than the admittedly superb Thrustmaster T300 RS (see p58). The Thrustmaster TMX Force Feedback (see p59) is £65 cheaper, but it lacks the G920's finesse, solid pedal base with clutch and the realistic-feeling steering wheel and paddle shifters. If around £100 is your limit, the TMX Force Feedback is a decent buy, but for £180, the G920 is bang on the money and, unlike the Thrustmaster, you can add a gear shifter for under £50 too.

PERFORMANCE	DESIGN	OVERALL SCORE
31/35	32/35	
VALUE		
25/30		88%

VERDICT

Not quite as lavish as the Thrustmaster T300 RS, but the G920 is a great all-rounder and its optional gear shifter is half the price of Thrustmaster's too.

Speedlink Black Bolt / £45 inc VAT

SUPPLIER www.amazon.co.uk / MODEL NUMBER SL-650300-BK

Speedlink's Black Bolt offers a way into the world of force feedback for just £45, forgoing mains-powered force feedback in favour of a subtler, USB-powered vibration effect. The wheel compensates for the lack of power with a fair degree of spring-back resistance as standard – it doesn't feel quite right at first, but you get used to it. Our experience with the Black Bolt reminded us of using an arcade steering wheel, and it has quite a large dead zone as standard too, requiring some calibration, whereas the other wheels on test were great from the outset.

The wheel is small, but solid and pleasant to use, making it potentially useful if you're limited for space. The paddle shifters work well and are more substantial than those on the Trust wheel, but they're also noisy and clunky in action.

Meanwhile, there are 12 customisable buttons and two hot keys with some custom functions such as cruise control. There's no rubber or leather coating though – it's all



plastic, which doesn't feel great in your hands.

Also, one major issue with the Black Bolt is that the sucker cup-mounted base simply doesn't adhere to surfaces with any kind of texture – only glass or glossy finishes will hold it. However, the suckers offer a good amount of staying power once they're secured.

The pedals are also small and their base moves around quite a bit, lacking the grip of the larger sets on test – even the Trust



wheel's pedals are much more substantial. It feels a little flimsy too, with none of the non-linear braking on offer from the Logitech and Thrustmaster sets. Once calibrated, the Black Bolt worked well in Dirt Rally, with just a 60-second configuration needed for some of the controls. It didn't feel precise in F12016 though – it's better suited to arcade or rally driving where you throw the car around from lock to lock. On the plus side, the weak force

Trust 20293 GXT 288 / £66 inc VAT

SUPPLIER www.argos.co.uk

Despite gear shifters being popular on real cars, especially in the UK where manual gearboxes are common on road cars, they're often optional on racing wheels. Logitech's add-on shifter for the G920 costs only a little less than the Trust 20293 GXT 288 as a whole, but as well as paddle shifters, the Trust also includes a gear shift lever. Sadly, though, it only behaves like a shifter you might find in a sporty automatic; you can only shift up or down, rather than to a specific gear. However, it adds an interesting dynamic if you're not keen on paddle shifters and don't want to use the fully automatic option.

Alternatively, you can also use it as a makeshift handbrake, although it uses the same assignments as the paddle shifters for up and down gears, so you can't use both at the same time. The shifter box is also fixed to the right side of the wheel, although Brits



can't expect everything at this price. Amazingly, despite its price, Trust has managed to include faux leather on the wheel for some added realism, which feels so much better than the Speedlink's plastic. The mount is also excellent and the pedals are much more substantial than the Speedlink pedals, being nearly on a par with those on the Thrustmaster TMX Force Feedback.

However, while the wheel and mount feel solid, the wheel's motion does clunk a bit as it

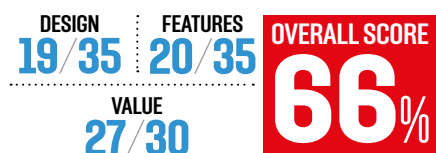


passes the centre, alluding to some fairly simple gearing inside. Like the Speedlink, the 20293 GXT 288 also lacks mains-powered force feedback and just has subtle vibration. It's still effective, though, and provides good feedback over rough terrain for knocks and bangs. The Trust's wheel is fairly light and doesn't have the excessive spring-back of the Speedlink, although its paddle shifters are really just large buttons, whereas all the other wheels have fully fledged paddles.

feedback didn't reduce too much of the fun – you can still feel the bumps, apexes and knocks, but there's very little reactive resistance from driving – an issue the spring-back resistance tries to hide.

Conclusion

The Speedlink Black Bolt costs a quarter of the price of the Logitech G920 and well over half the price of the Thrustmaster TMX Force Feedback. Not everyone can afford over £100 for a racing wheel and as long as you have a suitable surface for the suction cups, the Black Bolt can be fun. However, the Trust 20293 GXT 288 feels more realistic, while offering better pedals, a larger wheel and a better mounting mechanism, making it a better buy if you can find the extra money.



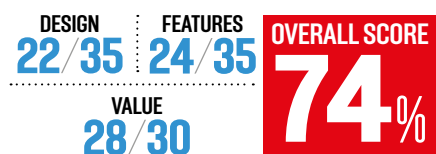
VERDICT

Small, inexpensive and entertaining, but we recommend spending a little more money on the larger, superior Trust.

After a quick setup to dish out the controls for each axis in Dirt Rally, the Trust worked fine, although there was a lack of sensitivity in the pedals compared with the more expensive sets. The manual shifter worked well, although it's quite noisy, but the wheel offers huge amounts of fun for the money.

Conclusion

We're impressed by what the 20293 GXT 288 offers for its price. The wheel feels nearly as robust as more expensive sets and the pedals are much better to use than the Speedlink's pedals. If the Thrustmaster TMX Force Feedback is too much of a stretch for your budget, the Trust will still be £70 well spent if you're a keen virtual racer.



VERDICT

Impressively robust for the money and even sports a gear lever, although it lacks proper force feedback.

Serious sims

Most of the wheels we've reviewed this month come as a complete set out of the box, but one or two of them have optional add-ons that you can buy to enhance your racing experience and notch up the realism. Logitech offers its Driving Force Shifter for a very reasonable £45, which sports a six-speed H-pattern shift that's ideal for using with the G920's clutch pedal. It also includes a desk mount, so it can easily be added alongside your G920 wheel on the left or right.



Logitech offers an optional gear shifter to add extra realism

Thrustmaster goes even further with its customisation, offering the gorgeous-looking TH8A shifter for around £110, which offers multiple shift plates for different configurations and can be mounted on your desk or chair arm. There's also a Thrustmaster triple-pedal T3PA-Pro pedal unit, which can be floor-mounted or suspended, plus replica pedals for cars such as the F1 Ferrari, Ferrari 599XX Evo and Ferrari 458, allowing you to swap out the wheel on certain Thrustmaster models, such as the T300 RS, for a more realistic setup.



Fanatec offers seriously realistic racing kit

Of course, part of the challenge of creating a realistic-feeling setup is mounting your racing peripherals in the correct place, which isn't always possible if you're sitting at a desk. However, there are plenty of options for custom racing seats. The Next Level Racing GTUltimate V2 racing cockpit, for example, is a full-on racing chair with a harness, and mounting points for Logitech, Thrustmaster

and Fanatec racing peripherals. If this chair takes your fancy, it's available from www.overclockers.co.uk for £600 inc VAT.

Meanwhile, a relatively new company to the racing peripheral scene is Fanatec (www.fanatec.com). If you're serious about your virtual racing, and want to go beyond what the likes of Logitech can offer, then you'll want to investigate some of Fanatec's hardware. You can select your hardware from a number of bundles, or just choose the parts you want. However, you can also create your own customised

Fanatec racing cockpit, complete with single or triple monitor stands, racing seat, handbrake, shifter and wheel. We chose from some of the cheaper options, including a handbrake, shifter, wheel, seat and monitor stand, which came out at €3,661 (around £3,130), so such a setup isn't for cash-strapped gamers, and you'll need a sizeable space to set it up too. However, if you want to build your own proper racing simulator, Fanatec offers some seriously good kit.

Finally, if building your own simulator isn't possible for spatial or financial reasons, and you don't happen to be friendly with the boss of an F1 team, then take a look at www.letsrace.co.uk. The company offers F1 simulator racing sessions that start from just £15 inc VAT, and can include a 30-minute race with a grid start.



The Next Level Racing GTUltimate V2 racing cockpit is a full-on racing chair with a harness



Thrustmaster T300 RS / £214 inc VAT

SUPPLIER www.box.co.uk / MODEL NUMBER 4168049

If you want some serious power from a very realistic steering wheel set, then the Thrustmaster T300 RS should definitely be on your shortlist. This premium set features an industrial-class brushless motor and even requires a fan to kick in after lengthy gaming sessions. However, the result is some monstrous force feedback that's both powerful and detailed from this mains-powered unit.

At a price of £214 inc VAT, the Thrustmaster T300 RS is the most expensive wheel on test, yet it lacks the clutch pedal present on the Logitech G920 Driving Force (see p55) and isn't equipped with a manual gear shifter either. Thankfully, paddle shifters are present, although we were a tad disappointed with them – they feel rather flat and tinny compared with those of the Logitech G920. However, the T300 RS makes up for this shortcoming with its great-feeling textured rubber coating around the whole wheel, and it can work seamlessly with a PC, PS3 or PS4 as well.

The wheel offers a full 1,080 degrees of rotation, all at the mercy of the mighty force feedback system, and the latter can even reduce the rotation to 270 degrees using software. The latter setting makes its behaviour more akin to an F1 car, so the T300 RS is just as happy doing handbrake turns in

Rally Cross as it is tangling around Silverstone with Lewis Hamilton. It uses a similar mount to the TMX Force Feedback (see opposite), with around 4cm of vertical clearance for your desk to slot into the clamp, but the T300 RS has a slightly tweaked securing mechanism that's easier to use than that of the TMX.

Whether you're using a PC or a PlayStation, it's simple to get the T300 RS up and running thanks to good support in most games, with Dirt Rally already sporting a profile just for this wheel set, although you may want to tweak some of the 13 customisable buttons to your own liking. You can also remove the wheel entirely to enable you to fit a custom wheel, such as Thrustmaster's very tasty-looking Ferrari 458 or Ferrari F1 wheels, for some added realism.

Hit the track and the force feedback becomes exhausting after a while, but it offers immense fun in both Dirt Rally and F1 2016, especially when you encounter understeer or feel the apexes – the T300 RS definitely has an edge over the Logitech G920 in this respect. However, on the flip side, the pedals didn't feel quite as sturdy as those of the Logitech, although leaning your heels on the base does prevent any movement. The T300 RS' brake was noticeably stiffer than the accelerator too – a touch of realism that most pedal sets forget.

Conclusion

Despite its prowess, the Thrustmaster T300 RS finds itself in a bit of a no-man's-land. It's more expensive than the slightly less powerful, but better-rounded Logitech G920. With the latter's clutch pedal and £45 gear shifter you'd get a much cheaper and well-rounded package than spending the extra £100 on Thrustmaster's TH8A gear shifter with this set. However, the TS 300 RS is more akin to a starting point, with Thrustmaster offering a host of fantastic add-ons, from clutch-equipped metal pedal sets to replica wheels and gearsticks with multiple shift plates. As a result, you'd need to invest more than the asking price here to do it justice. The end result, while costing a small fortune, would be awesome, but as a full set, the Logitech G920 and its optional gear shifter offers better value for money.

DESIGN	FEATURES	OVERALL SCORE
32/35	32/35	86%
VALUE		
22/30		

VERDICT

Very lively force feedback and a great quality wheel, but it's more of a starting point rather than a complete set, and it's also expensive.



Thrustmaster TMX Force Feedback / **£118** inc VAT

SUPPLIER www.morecomputers.com / **MODEL NUMBER** 4468008

Thrustmaster's TMX Force Feedback wheel and pedals set comes in at £118 inc VAT, making it significantly cheaper than the Logitech G920 Driving Force (see p55), but also nearly twice the price of Trust's surprisingly good 20293 GXT 288.

This middle ground gets you a solid example of a steering wheel, though, with a very solid mount that includes padding to protect the surface on which you mount it, and it has clearance for up to 4cm-thick desks, plus the all-important mains-powered force feedback system.

Full-sized paddle shifters are included, and while they don't feel quite as realistic as the paddles on the Logitech, they're plenty good enough for taking a virtual Nissan GTR for a spin. The wheel doesn't have a complete coating to hide the plastic shell, but it does have large rubber grips either side. These grips proved to work exceptionally well, even compared with the fully covered rubber and leather wheels on the two more expensive products on test this month, which often felt like they'd benefit from a pair of driving gloves. However, your hands will also get a little sore when using the TMX Force Feedback. It's chunky too, so it feels more substantial and realistic than the Trust wheel.

Meanwhile, the pedals are life-sized and made from steel, although they're quite

simple and light compared with those sporting the two more expensive sets on test, and they can be prone to moving if you don't lean your heels on the base when you're using them.

Once you've installed the drivers and software, most games will allocate presets for the TMX Force Feedback without any problems – this was the case in *Dirt Rally*, for example, so setting it up should be plain sailing.

There are also 12 programmable buttons and a D-pad, with the red button allocated as a handbrake in some games. These controls can be tricky to use if your arms are going between locks, but this set of buttons is closer to the edge of the unit than the buttons on the more expensive Thrustmaster T300 RS, which is good if you're a rally fan. Meanwhile, the force feedback system feels firm and deliberate, if lacking in variation, but it has plenty of grunt to test your forearms either through collisions or understeer; it feels in a different league to the Trust wheel's subtler feedback.

The wheel also offer 900 degrees of rotation, and the optical sensor in the wheel feels very precise, making for a good experience in F1 racing. It also felt very smooth and quiet, thanks to its belt and gear system

Conclusion

There's an awful lot to like about the TMX Force Feedback, even though it costs over

£100. The mains-powered force feedback system feels brutal at times (although its bigger sibling is even more demanding in this respect), and the quality is what you'd expect given its price tag – you really notice the difference when you move between the TMX Force Feedback and the Trust wheel.

You can consider adding Thrustmaster's optional gear shifter to this setup as well, but doing so will bring the total price to £218 inc VAT. That total sum isn't far off the price of the Logitech G920 when you add its optional shifter, which would be a slightly better package overall, especially with the addition of a clutch pedal. However, as a standalone unit, the TMX Force Feedback is powerful, sturdy and worth the extra cash over the Trust 20293 GXT 288. Just be prepared for some sore arms and hands.

DESIGN	FEATURES	OVERALL SCORE
29/35	29/35	
VALUE		
26/30		84%

VERDICT

A beast of a wheel for a little over £100, with a solid mount and a brutal force feedback system, although it's a shame the optional gear shifter is so expensive.

PC system reviews

GAMING PC

Yoyotech BlackBox Strix / £2,899 inc VAT

SUPPLIER www.yoyotech.co.uk

Yoyotech's BlackBox certainly lives up to its name. It's built around the huge, though highly flexible, Be Quiet! Dark Base Pro 900 (see Issue 158, p24). It measures 243mm wide, 585mm tall and weighs 14kg, while sporting brushed aluminium panels and meshed air intakes.

Yoyotech has spruced up this smart, dark case by illuminating the interior with red LED strips, and the Asus motherboard and graphics card have crimson lighting. The red theme extends to the water-cooling system, which comes from EKWB. Red coolant courses from the combined EK-XRES 140 Rev0 D5

reservoir and pump to the Supremacy EVO waterblock, which is made from transparent acrylic, showing the coolant flowing around the CPU. The liquid is chilled by a CoolStream PE 240 radiator, which is chunky but barely visible, thanks to the case's cavernous roof.

The red lights glow through the tinted, tempered glass side panel, which is extremely sturdy, and the case's build quality is excellent elsewhere.

The system is tidy too. Cables are kept organised at the front, and behind the motherboard tray they run in perfect lines, with numerous spare plugs alongside empty fan connectors. The EVGA 750GQ PSU doesn't have braided cables, but that's a tiny quibble, especially when it has a modular design and an 80 Plus Gold rating.

Upgrade room isn't great. The motherboard has the usual selection of slots, but the water-cooling gear eliminates room for extra hard disks, and there's only one free SSD bay. That's not a big problem for most people any more, though, and Yoyotech has made good use of the Dark Base chassis' size for complex cooling and improved noise reduction.

The case fans are 140mm SilentWings models, noise-dampening materials line the side, roof and front panels, and the hard disk,

PSU and motherboard sit on rubberised washers.

Yoyotech has opted for a 6-core Intel Core i7-6850K, with its 3.6GHz stock speed improved to 4.3GHz. The extra two cores have a negligible effect in games, but they should improve this machine's multi-tasking abilities against quad-core CPUs.

The Asus Strix GTX 1080 arrives with its Gaming Mode enabled, which boosts the core from 1607MHz to 1759MHz and the boost clock to 1898MHz. The familiar Samsung 950 Pro SSD also provides speedy solid state storage, and the core spec is accompanied by 32GB of 3200MHz memory – a large amount of RAM, although only certain applications will

be able to take advantage of it.

Then there's the Strix X99 Gaming motherboard, which follows the current trend for RGB lighting with LEDs in its heatsinks and PCI-E slots, and it also delivers on-board power and reset buttons, plus a POST display. As a fully fledged X99 board, it has eight memory slots, and dual-band 802.11ac Wi-Fi.

Finally, Yoyotech's warranty includes three years of labour protection but only a year of the all-important parts coverage, which is okay, but other system builders offer more parts coverage as standard. The BlackBox also offers 30 days of collect and return service, but it then reverts to a return to base deal.

Performance

The 6-core processor didn't disappoint in our heavily multi-threaded video encoding test, where it delivered an exceptional score of 389,625 – far quicker than quad-core systems. The SSD results were great too – the Samsung drive's read and write speeds of 2,122MB/sec and 1,398MB/sec are superb.

The overclocked GTX 1080 card delivered impressive gaming performance. Its 1080p minimums sometimes exceeded 100fps, and it managed at least 59fps in all our 2,560 x 1,440 gaming tests. It can handle a bit of 4K gaming too. It never dropped below 30fps in The Witcher 3 or Crysis 3, and it managed a borderline playable minimum of 28fps in Fallout at Ultra settings – dropping down to the High preset will easily make this game smoothly playable.



/SPECIFICATIONS

CPU 3.6GHz Intel Core i7-6850K overclocked to 4.3GHz

Motherboard Asus ROG Strix X99 Gaming

Memory 32GB G.Skill TridentZ 3200MHz DDR4

Graphics Asus Strix GeForce GTX 1080 8GB

Storage 256GB Samsung 950 Pro M.2 SSD; 2TB Seagate Barracuda hard disk

Case Be Quiet! Dark Base 900 Pro

Cooling CPU: EKWB Supremacy EVO waterblock, EKWB CoolStream PE 240 radiator with 2 x 120mm fans, EKWB XRES 140 Rev0 D5 reservoir/pump; GPU: 3 x 90mm fans; front: 2 x 140mm fans; rear: 1 x 140mm fan

PSU EVGA 750GQ 750W

Ports Front: 4 x USB 3, 2 x audio; Rear: 2 x USB 3, 1 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 4 x USB 2, 1 x PS/2, 1 x Gigabit Ethernet, 1 x optical S/PDIF, 5 x audio

Operating system Microsoft Windows 10 Home 64-bit

Warranty One year parts and labour, followed two years labour only, with first month collect and return

- 1** The water-cooling gear comes from EKWB
- 2** Although it's water-cooled, the CPU still gets hot at full load
- 3** The Asus Strix GTX 1080 card is great for high-res gaming

Thanks to its properly tuned water-cooling gear, the BlackBox is also exceptionally quiet. When it's idle, the Yoyotech is very quiet, and barely louder during stress tests, where its low murmur is only just audible – you simply won't hear this PC if it's sitting under your desk.

However, those stress tests revealed that Yoyotech has been too ambitious with its overclock. The CPU's peak temperature of 100°C is too hot for comfort, prompting the CPU to throttle to its default 3.6GHz speed. It's a black mark against the BlackBox, because few people buy a 6-core PC if they're not planning to run some CPU-intensive work on it.

Our temperature test has a couple of caveats: only one core reached 100°C, with the rest of them peaking between 89°C and 95°C, and the system remained stable during the tests. It would only take a little fan-speed tweaking, or a slightly less ambitious overclock, to sort it out, which we advise discussing with Yoyotech if you plan to buy this PC. On the plus side, the GPU's delta T of 45°C is great.

Conclusion

The BlackBox succeeds in several critical areas. The overclocked GTX 1080 tackles almost any gaming scenario, the 6-core processor handles multi-threaded workloads well and the SSD is fast. Meanwhile, the case is large and sturdy and its noise-dampening features work well; the Yoyotech is close to silent despite its power.



However, the processor temperature is an oversight, showing that the overclock is a tad too ambitious. The BlackBox is expensive too – quad-core machines with GTX 1080s deliver equal gaming pace for less money, but you're really paying for a proper water-cooling system here, as well as a 6-core CPU. Ultimately, though, the heat keeps this PC from higher scores, but it's otherwise a well-made and well-balanced bruiser, ticking all the performance boxes while remaining subtle and smart. If you can get Yoyotech to reduce the overclock a little then it will be a great machine.

MIKE JENNINGS

CPC REALBENCH 2015 GIMP IMAGE EDITING



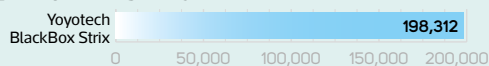
HANDBRAKE H.264 VIDEO ENCODING



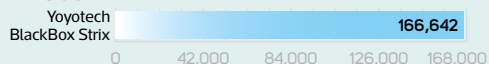
LUXMARK OPENCL



HEAVY MULTITASKING



SYSTEM SCORE



INTEL REFERENCE: 145.6%

SPEED
24/25

DESIGN
21/25

HARDWARE
23/25

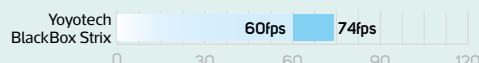
VALUE
19/25

OVERALL SCORE

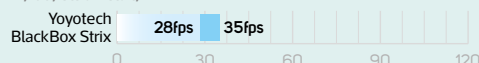
87%

FALLOUT 4

2,560 x 1,440, Ultra Detail, TAA



3,840 x 2,160, Ultra Detail, TAA

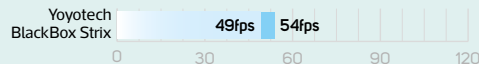


WITCHER 3

2,560 x 1,440, High Detail, AA on



3,840 x 2,160, High Detail, AA on



CRYSIS 3

2,560 x 1,440, Very High Detail, 0x AA



3,840 x 2,160, Very High Detail, 0x AA



Minimum Average

VERDICT

Impressive speed and near-silent operating inside a big, sturdy case – but the overclocked CPU gets too hot.

GAMING PC

Mesh Elite Kryptonite P5 / £1,350 inc VAT

SUPPLIER www.meshcomputers.com

The Thermaltake P5 is one of the wildest enclosures on the market, making an eye-catching canvas for Mesh. The glass front means all the insides can be seen, and it's only attached to the sturdy steel back by four chrome-effect struts, so the top and sides are exposed to the air. It looks stunning, and Mesh's choice of a green chassis makes a big impact. The thick back panel, PCI-E brace and the small shelf that holds the cylindrical reservoir are all finished in the same bright shade of green.

Mesh has gone to town on the cooling and lighting too. The Thermaltake PR15 pump and reservoir feed coolant to the Pacific W1 waterblock, with the liquid chilled by a Thermaltake RL120 radiator mounted at the top of the chassis with a single 120mm fan.

Meanwhile, LED strips surround the motherboard, and a neat Thermaltake Lumi Colour 256C unit controls the colour, tone and pattern of the lights – although naturally, it's tuned to bright green. A second Lumi Colour unit controls the 140mm Thermaltake Riing fan, while the Asus Aura graphics card and motherboard have their RGB LEDs set to the same colour.

It makes for a striking system, and Mesh has done well with the build. The open nature of the chassis means cables are visible, but Mesh has routed them well and hidden plenty of cabling behind the thick motherboard tray.

The open chassis also means that every free motherboard slot, socket and connector is easily accessible. The chassis is a little wobbly, but that isn't a problem if it's standing still.

In terms of specs, the Core i7-6700K is overclocked to 4.5GHz, which is a little lower than some machines we've reviewed recently. It's paired with 16GB of 2400MHz DDR4 memory, which will be fine, but again, it's a little slow compared with other high-end PCs.

Mesh has also deployed an Asus GTX 1070 in the Kryptonite P5. This pricey Pascal card has 1,920 stream processors and 8GB of memory, but it doesn't have the GDDR5X chips of the GTX 1080. It does, however, have a beefy overclock: its core frequency has been improved from 1506MHz to 1633MHz, with the boost speed

rising from 1683MHz to 1835MHz.

Meanwhile, Windows 10 is installed on a 250GB Samsung 750 EVO SSD. It's a low-cost SSD for system builders with TLC flash, so it's more akin to Samsung's older, mid-range consumer drives than more recent 3D V-NAND products. It's better than a hard drive, but nothing special.

Then there's the Asus Z170 Pro Gaming Aura motherboard, which has the aforementioned LEDs, and loads of USB 3 and USB 3.1 ports on the back. It also sports Intel GameFirst Ethernet and Asus SupremeFX audio, but there are no on-board buttons or POST code display.

Finally, the FSP Hydro G is a decent 750W modular PSU with an 80 Plus Gold certification.

Mesh sells this PC with its Gold warranty – a two year parts deal with a year of collect and return service and a lifetime of

labour coverage, which is a fair enough deal – it's good to see two years of parts coverage.

Performance

The GTX 1070 had no problem with 1080p and 2,560 x 1,440 gaming. Its slowest result at 1080p was a smooth 73fps in Crysis 3, which dropped to a still fast 46fps at 1440p. The results were even better in Fallout 4 and The Witcher 3. Nvidia didn't design the GTX 1070 as a proper 4K gaming card, so that's where the Mesh started to falter. Its 35fps in The Witcher 3 is good, but it fell below our 25fps borderline playable target in both our other test games – you'll need to drop the detail in order to run these titles smoothly.

Meanwhile, the 500MHz overclock on the Core i7-6700K saw it deliver an overall benchmark score of 142,211. That's ample for intensive applications and games, and not far behind PCs with heftier overclocks. The SSD didn't deliver any surprises though. The modest drive returned speeds of 521MB/sec and 500MB/sec in our read and write tests, although our recent Labs test (see Issue 158, p43) shows that this drive struggles in more intensive workloads, and its speeds are a long way behind NVMe M.2 drives either way.

However, while the Mesh's liquid-cooling system looks good, it's only cooled by a small 120mm radiator with a single fan, which struggled to keep the overclocked CPU in check. The CPU temperature reached a peak delta T of 77°C in our stress tests, which means it ramped up to 100°C when under constant load. That's worryingly high, even if most users won't run the CPU at 100 per cent load for extended periods. It also means that the overclock is entirely eliminated during



/SPECIFICATIONS

CPU 4GHz Intel Core i7-6700K overclocked to 4.5GHz

Motherboard Asus Z170 Pro Gaming Aura

Memory 16GB Corsair Vengeance LPX 2400MHz DDR4

Graphics Asus GeForce GTX 1070 8GB

Storage 256GB Samsung 750 EVO SSD, 2TB Seagate Barracuda hard disk

Case Thermaltake P5 Green Edition

Cooling CPU: Thermaltake Pacific RL120 with 1x 120mm fan; GPU: 3 x 80mm fans; front: 1x 140mm fan

PSU FSP HydroG 750W

Ports Front: 2 x USB 3, 2 x USB 2, 1 x audio; rear: 4 x USB 3, 1 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 2 x USB 2, 1 x PS/2, 1 x Gigabit Ethernet, 1 x optical S/PDIF, 5 x audio

Operating system Microsoft Windows 10 Home 64-bit

Warranty Two years parts with one year of collect and return cover, lifetime labour

- 1** The cooling system and LEDs all match the case's green colour scheme
- 2** The Asus Strix GTX 1070 has no trouble dealing with 2,560 x 1,440 gaming
- 3** The radiator's single 120mm fan can't quite tame the overclocked CPU

stress tests, with the CPU throttling down to 4GHz. On the plus side, though, the GPU temperature only peaked at a comfortable delta T of 41°C.

Noise is a consistent issue too. When idle the Mesh is louder than most other gaming machines, with most of the noise coming from the CPU cooler's single fan, and exacerbated by the open sides of the case. The noise never increased during stress tests, but it's a constant irritation unless speakers or a headset are used to drown it out.

Conclusion

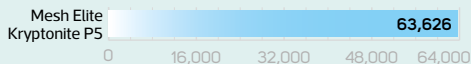
The Mesh's green Thermaltake chassis is accompanied by impressive looking water-cooling gear and lighting, and the overclocked components deliver good application performance and gaming power at 1080p and 2,560 x 1,440. However, the CPU gets too hot, the noise levels are too loud and the SSD isn't particularly quick. Mesh clearly has the aesthetics and build quality nailed, which is great to see, but the Elite Kryptonite P5 needs better CPU cooling, lower noise levels and a more balanced specification.

MIKE JENNINGS



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GIMP IMAGE EDITING



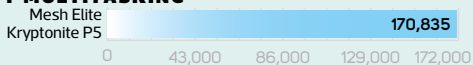
HANDBRAKE H.264 VIDEO ENCODING



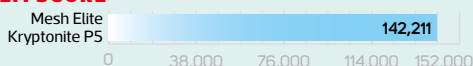
LUXMARK OPENCL



HEAVY MULTITASKING



SYSTEM SCORE



INTEL REFERENCE: 124.25%

SPEED
21/25
HARDWARE
21/25

DESIGN
19/25
VALUE
20/25

OVERALL SCORE
81%

VERDICT

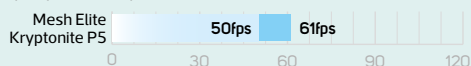
Reasonable speed and specifications, but the Kryptonite P5 is noisy and also needs better cooling to cope with its overclocked CPU.

FALLOUT 4

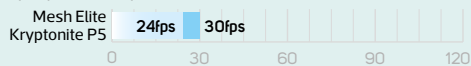
1,920 x 1,080, Ultra Detail, TAA



2,560 x 1,440, Ultra Detail, TAA



3,840 x 2,160, Ultra Detail, TAA



THE WITCHER 3: WILD HUNT

1,920 x 1,080, High Detail, AA on



2,560 x 1,440, High Detail, AA on



3,840 x 2,160, High Detail, AA on

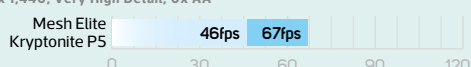


CRYSIS 3

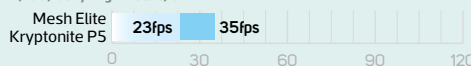
1,920 x 1,080, Very High Detail, 0x AA



2,560 x 1,440, Very High Detail, 0x AA



3,840 x 2,160, Very High Detail, 0x AA



Minimum Average

GAMING PC

Box Cube Ranger / £2,300 inc VAT

SUPPLIER www.box.co.uk

The Box Cube Ranger is an imposing-looking system. Thanks to its vast In Win 509 chassis. The 509 is a steel-skeleton behemoth with tempered glass side and front panels, and it weighs a whopping 14kg without any components installed, while measuring 527mm tall and a huge 578mm long.

The size means there's ample room for the Cube Ranger's components and cooling gear. Two 140mm Corsair fans usher air into the case, and four of the same units are attached to the Corsair Hydro H115i's 240mm CPU cooler radiator. This radiator is attached to a hefty steel beam that runs through the case, surrounding the motherboard. It's painted red to match this chassis, which is a Republic of Gamers special edition with the Asus brand logo on the side panel.

The crimson theme doesn't stop there: lights along the bottom and top edges of the case illuminate the interior, and the intake and exhaust fans also have red LEDs. The In Win logo on the front panel is programmed to glow red too. The sturdy steel and thick glass means this case has superb build quality, and its sheer size means the components are easily accessible.

That said, there isn't much room for storage drives. There are three 2.5in brackets and a single free hard disk bay. Box's build is inconsistent too – it's great to see the braided cables, and the front of the system is reasonably tidy too, but the rear is a total mess, with no effort made to keep cables neat. You won't see this area for the most part, admittedly, but other system builders take more care here.

In terms of components, the Box makes a great first impression by including an Asus Strix GeForce GTX 1080 card. This Strix card has three fans and RGB lighting, but Box only runs the GPU at its stock speed of 1607MHz by default. If you want a little boost, though, the Strix card includes an overclocked mode that runs the GPU at 1632MHz.

The rest of the specification is high-end. Box has upped the Core i7-6700K CPU's vcore to 1.4V to enable a high overclocked speed of 4.7GHz, which about as high as we see the 6700K go before it becomes unstable. The 16GB of 3000MHz Corsair LED memory is fast and capacious too, and the red LEDs complement the rest of the system. Meanwhile, storage is divided between a super-fast 256GB Samsung 950 Pro SSD and a 2TB hard disk.

Then there's the Asus ROG Maximus VIII Ranger, which is an accomplished, good-looking motherboard board with heatsinks clad in red and gunmetal grey. The power and reset buttons are easy to reach, there's a POST display and the board also supports Intel



GameFirst Ethernet and Asus SupremeFX audio. Meanwhile, the backplate has the now-familiar loadout of USB 3.1 Type-A and Type-C ports, along with two normal USB 3 ports and a USB Flashback button.

The rig is all powered by a Corsair HX850i PSU. It's a heavy-duty modular unit with an impressive 80 Plus Platinum rating, and the huge amount of power means there's ample headroom for adding a second GPU.

We have no issues with the Box's specification, which is impressive in every department, but Box also offers two alternative specifications if this GTX 1080-powered rig is too expensive or overpowered. Both simply involve GPU changes; a machine with the GTX 1070 costs £2,050 inc VAT, while a system with the GTX 1060 is priced at £1,900 inc VAT.

All these systems are protected by a two year parts and labour warranty with a year of collect and return coverage, which is a good deal.

Performance

The Cube Ranger had no trouble dealing with any of our test games at 2,560 x 1,440, and the stock-speed Strix GTX 1080 card just about handled the intense demands of 3,840 x 2,160 gaming. Its best result came in The Witcher 3, where its minimum of 42fps made for smooth 4K gaming. The Ranger beat our borderline minimum of 25fps in our other test games too, with a score of 26fps in Fallout 4 and 28fps in Crysis 3 – you'll only need to drop the settings a little to make gameplay smooth in these games.

We were able to eke out more performance from the Ranger by activating the Strix card's overclocked mode too. With this option selected, the minimum frame rate went up by 1fps in Crysis 3 and Fallout 4, and by 1fps in The Witcher 3.

The Ranger was really impressive in application tests as well. It sauntered through individual benchmarks with ease, and then delivered an overall score of 146,281 – far quicker

/SPECIFICATIONS

CPU 4GHz Intel Core i7-6700K overclocked to 4.7GHz
Motherboard Asus Maximus VIII Ranger
Memory 16GB Corsair Vengeance LED 3000MHz DDR4
Graphics Asus GeForce GTX 1080 8GB
Storage 256GB Samsung 950 Pro M.2 SSD; 2TB Seagate Barracuda hard disk
Case In Win 509 ROG Edition
Cooling CPU: Corsair Hydro H115i with 4 x 140mm fans; GPU: 3 x 70mm fans; front: 2 x 140mm fans; rear: 1 x 140mm
PSU Corsair HX850i 850W
Ports Front: 4 x USB 3, 2 x audio; rear: 2 x USB 3, 1 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 4 x USB 2, 1 x PS/2, 1 x Gigabit Ethernet, 1 x optical S/PDIF, 5 x audio
Operating system Microsoft Windows 10 Home 64-bit
Warranty Two years parts and labour, with first year collect and return, and second year return to base

- 1** The LEDs, case structure and motherboard are clad in matching red
- 2** The CPU is overclocked to 4.7GHz, and cooled by a Corsair H115i
- 3** The Asus Strix GTX 1080 card is fast and well built, but it runs at stock speed

than our reference rig, and on a par with other recent overclocked PCs. Storage is fast too – the Samsung SSD zipped through our read and write tests at 2,079MB/sec and 1,402MB/sec respectively.

Despite the CPU overclock, the Box also impressed in thermal tests. Its CPU and GPU delta T figures of 59°C and 53°C are fine. The fan noise is low too. The Ranger was barely audible when idle and not much noisier during stress tests – at its peak, it was quieter than most other gaming systems, and much quieter than the small form factor PCs we've seen recently.

Conclusion

The Ranger offers solid performance, cool thermals, quiet operation, good looks and a sturdy case. However, its build quality is sometimes messy, and it's also comparatively expensive for the spec on offer. As a point of comparison, the CyberPower Hyper Liquid 100 (see Issue 158, p60) offers the same CPU, GPU and SSD with custom water cooling for just £1,999 inc VAT. It might be a small form factor system that isn't overclocked as far, but it demonstrates the premium you're paying for the Box machine.

The Box Cube Ranger's price is undoubtedly bumped up by the inclusion of a premium case, PSU and Asus Strix

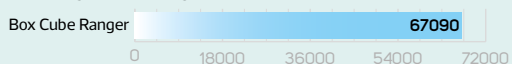


graphics card, which are all worthy inclusions, but it's disappointing that Box only runs the graphics card at stock speed by default.

The Cube Ranger is a fast, cool and good-looking system, but it needs a little more polish to justify its price.

MIKE JENNINGS

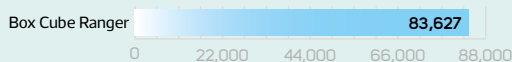
CPC REALBENCH 2015 GIMP IMAGE EDITING



HANDBRAKE H.264 VIDEO ENCODING



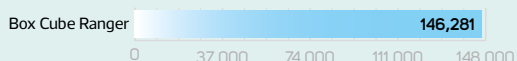
LUXMARK OPENCL



HEAVY MULTITASKING



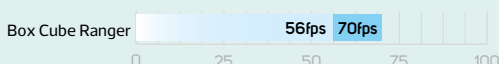
SYSTEM SCORE



INTEL REFERENCE: 127.81%

FALLOUT 4

2,560 x 1,440, Ultra Detail, TAA



3,840 x 2,160, Ultra Detail, TAA



THE WITCHER 3: WILD HUNT

2,560 x 1,440, High Detail, AA on



3,840 x 2,160, High Detail, AA on

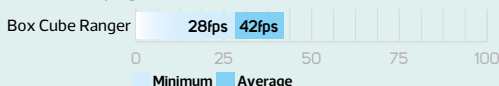


CRYSIS 3

2,560 x 1,440, Very High Detail, OX AA



3,840 x 2,160, Very High Detail, OX AA



SPEED
22/25

DESIGN
20/25

HARDWARE
22/25

VALUE
19/25

OVERALL SCORE
83%

VERDICT

Consistently fast with strong and striking aesthetics, but it needs more polish to justify its high price.

Elite

Our choice of the best hardware available

Build a home theatre PC

The parts you'll need to build an affordable, home theatre PC that's ideal for putting in the lounge and playing back all manner of video formats. This machine will handle general computing and media tasks with no trouble, and its dual-core Skylake CPU can even handle 4K video playback. Meanwhile, its super-quiet Noctua CPU cooler prevents it from making a racket.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Lian Li PC-Q09FNB with 300W FSP SFX PSU	www.overclockers.co.uk	Issue 149, p92	£125
	Intel Core i3-6100T	www.overclockers.co.uk	Issue 149, p92	£109
	Asus H110i-Plus D4	www.scan.co.uk	Issue 149, p92	£68
	8GB (2 x 4GB) Corsair Vengeance LPX 2133MHz DDR4 (CMK8GX4M2A2133C13)	www.scan.co.uk	Issue 149, p92	£43
	Noctua L9i	www.scan.co.uk	Issue 149, p93	£35
	Samsung SN-208FB	www.novatech.co.uk	Issue 149, p93	£18
	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£64
	Samsung 850 Evo 250GB	www.overclockers.co.uk	Issue 141, p51	£80
	Logitech K400 Plus	www.scan.co.uk	Issue 149, p93	£29
	Microsoft Windows 10 Home Retail USB drive	www.scan.co.uk	Issue 146, p17	£86
TOTAL				£657

Build a budget gaming PC

The parts you'll need to build a budget machine capable of playing the latest games at maximum settings on a 1080p monitor, and even some games at 2,560 x 1,440. The machine has a discrete graphics card, a Skylake dual-core CPU and DDR4 memory. The ASRock Extreme4 motherboard is also capable of base clock overclocking via a BIOS update.










	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	NZXT S340	www.overclockers.co.uk	Issue 137, p54	£65
	ASRock Z170 Extreme4	www.scan.co.uk	Issue 151, p84	£117
	Intel Core i3-6100	www.scan.co.uk	Issue 151, p18	£103
	8GB (2 x 4GB) Corsair Vengeance LPX 2400MHz (CMK8GX4M2A2400C16)	www.ebuyer.com	Issue 151, p83	£40
	Nvidia GeForce GTX 1060 3GB UPDATED	www.overclockers.co.uk	Issue 159, p43	£185
	Samsung 850 Evo 250GB	www.overclockers.co.uk	Issue 141, p51	£80
	SilverStone Argon AR01	www.scan.co.uk	Issue 132, p57	£26
	EVGA SuperNova GS 550W	www.awd-it.co.uk	Issue 146, p50	£73
	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£64
	Microsoft Windows 10 Home Retail USB drive	www.scan.co.uk	Issue 146, p17	£86
			TOTAL	£839



Build a mid-range PC

Work PC

The parts you'll need to build a solid quad-core PC with plenty of upgrade potential. This kit list gives you an all-in-one liquid cooler and a K-series Core i5 Skylake CPU, meaning you can overclock it and get some serious processing power. We've managed to get the Core i5-6600K Skylake CPU up to 4.6GHz, so it has some great performance potential. Also included is a solid EVGA PSU, a fast M.2 SSD and 16GB of high-speed DDR4 memory. The core configuration assumes you won't be doing any serious gaming, however, and it relies on Intel's integrated graphics.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	SilverStone Primera PM01	www.scan.co.uk	Issue 157, p25	£90
	Asus Maximus VIII Ranger	www.scan.co.uk	Issue 147, p44	£164
	Intel Core i5-6600K	www.overclockers.co.uk	Issue 145, p17	£210
	16GB 2666MHz Geil Dragon RAM (GWB416GB2666C15DC)	www.comwales.co.uk	Issue 158, p53	£74
	NZXT Kraken X41	www.alza.co.uk	Issue 138, p57	£77
	EVGA SuperNova GS 550W	www.awd-it.co.uk	Issue 146, p50	£73
	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£64
	Samsung SSD 950 Pro 256GB	www.shop.bt.com	Issue 149, p48	£171
	Microsoft Windows 10 Home Retail USB drive	www.scan.co.uk	Issue 146, p17	£86
			TOTAL	£1,009

Gaming PC










The graphics card you'll need to play current games at their maximum settings at 1080p and 2,560 x 1,440.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	1,920 x 1,080 and some 2,560 x 1,440 Nvidia GeForce GTX 1060 6GB UPDATED	www.scan.co.uk	Issue 159, p51	£239
	2,560 x 1,440 and some 4K Asus Strix GeForce GTX 1070 OC	www.ebuyer.com	Issue 156, p24	£465

Build a performance PC


Work PC

The parts you'll need to build a high-quality, fast PC that's ideal for multi-threaded workloads. This kit list features a high-quality, well-built case, a feature-rich motherboard and an Intel Skylake Core i7-6700K CPU. This processor's support for Hyper-Threading splits the resources of the CPU's four physical cores into a further four virtual cores, meaning it can effectively handle eight threads at once. There's also a solid Corsair 750W PSU, giving you plenty of headroom for overclocking and adding another GPU, 16GB of DDR4 memory, a high-speed M.2 SSD and a proper liquid-cooling system.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Cooler Master Cosmos SE	www.scan.co.uk	Issue 144, p41	£115
	Asus Maximus VIII Hero	www.overclockers.co.uk	Issue 146, p20	£188
	Intel Core i7-6700K	www.scan.co.uk	Issue 145, p17	£313
	16GB Corsair Vengeance LED 3000MHz DDR4 (CMU16GX4M2C3000C15R)	www.scan.co.uk	Issue 158, p56	£89
	Alphacool Eisbaer 240	www.aquatuning.co.uk	Issue 157, p28	£99
	Corsair RM750i	www.scan.co.uk	Issue 146, p55	£120
	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£64
	Samsung SSD 950 Pro 512GB	www.currys.co.uk	Issue 149, p48	£265
	Microsoft Windows 10 Home Retail USB drive	www.scan.co.uk	Issue 146, p17	£86
			TOTAL	£1,339

Gaming PC

The graphics card you'll need to play current games at their maximum settings at 2,560 x 1,440 and beyond.












	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	1,920 x 1,080 and some 2,560 x 1,440 Nvidia GeForce GTX 1060 6GB UPDATED	www.scan.co.uk	Issue 159, p51	£239
	2,560 x 1,440 and some 4K Asus Strix GeForce GTX 1070 OC	www.ebuyer.com	Issue 156, p24	£465
	Smooth 4K Nvidia Titan X	www.nvidia.co.uk	Issue 158, p20	£1,099



Build a high-end 6-core PC

Multi-threaded PC

The parts you'll need to build a PC with serious power in multi-threaded software, such as 3D rendering apps, video editing programs and optimised distributed computing software. The kit list features a 6-core LGA2011-v3 CPU, which is overclockable using the motherboard and top-end cooler listed. Also supplied is 16GB of RAM, a super-fast M.2 SSD, 1TB of extra solid state storage and Asus' superb X99 Deluxe II motherboard.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Phanteks Enthoo Luxe	www.eclipsecomputers.com	Issue 144, p53	£138
	Asus X99 Deluxe II	www.scan.co.uk	Issue 156, p43	£353
	Intel Core i7-6850K	www.overclockers.co.uk	Issue 156, p26	£530
	Nvidia GeForce GTX 1060 3GB	www.overclockers.co.uk	Issue 159, p43	£185
	16GB Corsair Vengeance LPX 2666MHz DDR4 (CMK16GX4M4A2666C16)	www.scan.co.uk	Issue 136, p14	£90
	EKWB EK-Predator 240 Rev 1.1	www.scan.co.uk	Issue 148, p30	£167
	Corsair RM750i	www.scan.co.uk	Issue 146, p55	£120
	Samsung SSD 950 Pro 512GB	www.currys.co.uk	Issue 149, p48	£265
	Samsung 850 Evo 1TB	www.cclonline.com	Issue 141, p51	£279
	Lite-On IHAS124-14	www.shop.bt.com	Issue 99, p108	£10
	Microsoft Windows 10 Home Retail USB drive	www.scan.co.uk	Issue 146, p17	£86
			TOTAL	£2,223

Gaming PC









Replace the Asus RX470 graphics card with another graphics card to enable 4K gaming on this system, or take advantage of the Core i7-6850K's 40 PCI-E 3 lanes and add two GPUs for smoother frame rates.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	2,560 x 1,440 and some 4K Asus Strix GeForce GTX 1070 OC	www.ebuyer.com	Issue 156, p24	£465
	Smooth 4K gaming Nvidia Titan X	www.nvidia.co.uk	Issue 158, p20	£1,099

Build a mini PC

Core components

The parts you'll need to build either PC. This kit list gives you a solid PSU, 16GB of RAM, an overclockable Skylake CPU, an all-in-one liquid cooler and Windows 10 Home 64-bit. Also included is a graphics card that can play current games at their maximum settings at 2,560 x 1,440, and a high-speed M.2 SSD.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Intel Core i7-6700K	www.scan.co.uk	Issue 147, p84	£313
	16GB Corsair Vengeance LED 3000MHz	www.scan.co.uk	Issue 158, p56	£89
	Corsair H80i	www.box.co.uk	Issue 147, p84	£87
	Nvidia GeForce GTX 1060 6GB UPDATED	www.scan.co.uk	Issue 159, p51	£239
	Samsung SSD 950 Pro 512GB	www.currys.co.uk	Issue 149, p48	£265
	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£64
	EVGA SuperNova GS 550W	www.awd-it.co.uk	Issue 146, p50	£73
	Microsoft Windows 10 Home Retail USB drive	www.scan.co.uk	Issue 146, p17	£86



Mini-ITX PC

The parts you'll need to build a pint-sized powerhouse.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Fractal Design Define Nano S	www.scan.co.uk	Issue 153, p22	£60
	Asus Z170i Pro Gaming	www.scan.co.uk	Issue 147, p26	£139
			TOTAL	£1,415










Micro-ATX PC

The parts you'll need to build a mini PC that doesn't take up as much room as a full-sized desktop.





	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Fractal Design Arc Mini R2	www.scan.co.uk	Issue 157, p53	£80
	Asus Maximus VIII Gene	www.overclockers.co.uk	Issue 147, p42	£185
			TOTAL	£1,481






Cases

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Budget ATX	NZXT S340	www.overclockers.co.uk	Issue 137, p54	£65
	Sub-£100 performance	SilverStone Primera PM01	www.scan.co.uk	Issue 157, p24	£90
	Sub-£100 ATX quiet	Fractal Design Define R5	www.scan.co.uk	Issue 137, p20	£100
	Sub-£150 full-sized ATX quiet	Nanoxia Deep Silence 5	www.quietpc.com	Issue 144, p50	£137
	Sub-£150 full-sized ATX	Phanteks Enthoo Luxe	www.eclipsecomputers.com	Issue 144, p53	£138
	Sub-£150 mid-size ATX	Cooler Master Cosmos SE	www.scan.co.uk	Issue 144, p41	£115
	Mini-ITX tower	Fractal Design Define Nano S	www.scan.co.uk	Issue 153, p22	£60
	Mini-ITX cube	Fractal Design Core 500	www.scan.co.uk	Issue 150, p20	£53
	Micro-ATX	Fractal Design Arc Mini R2	www.scan.co.uk	Issue 157, p53	£80



Graphics cards

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	1,920 x 1,080 gaming	Nvidia GeForce GTX 1060 3GB UPDATED	www.overclockers.co.uk	Issue 159, p43	£185
	2,560 x 1,440 gaming	Nvidia GeForce GTX 1060 6GB UPDATED	www.scan.co.uk	Issue 159, p51	£239
	2,560 x 1,440 and some 4K gaming	Asus Strix GeForce GTX 1070 OC	www.ebuyer.com	Issue 156, p24	£465
	Smooth 4K gaming	Nvidia Titan X	www.nvidia.co.uk	Issue 158, p20	£1,099






Power supplies

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Mid-range 550W	EVGA SuperNova GS 550W	www.awd-it.co.uk	Issue 146, p50	£73
	High-end 550W	Super Flower Leadex Platinum 550W	www.overclockers.co.uk	Issue 146, p52	£95
	Mid-range 750W	Corsair RM750i	www.scan.co.uk	Issue 146, p55	£120
	High-end 1.2kW	Corsair Professional Series AX1200i	www.box.co.uk	Issue 111, p40	£304







Networking

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Router	Asus RT-AC68U	www.cclonline.com	Issue 128, p88	£120
	Wi-Fi adaptor	Asus PCE-AC68	www.cclonline.com	Issue 128, p88	£68




Storage

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Hard disk	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£64
	500GB SATA SSD	Samsung 850 Evo 500GB	www.currys.co.uk	Issue 158, p44	£135
	1TB SATA SSD	Samsung 850 Evo 1TB	www.cclonline.com	Issue 141, p51	£279
	High-performance M.2 SSD	Samsung SSD 950 Pro 512GB	www.currys.co.uk	Issue 149, p48	£265
	NAS box	Synology DS216j	www.ebuyer.com	Issue 154, p28	£135






Monitors

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	24in monitor	Dell U2414H	www.scan.co.uk	Issue 129, p43	£196
	27in 2,560 x 1,440 FreeSync monitor	Acer XF270HU	www.overclockers.co.uk	Issue 155, p46	£400
	27in 2,560 x 1,440 G-Sync monitor	Asus ROG Swift PG279Q	www.scan.co.uk	Issue 155, p48	£699
	27in 4K FreeSync	ViewSonic XG2700-4K	www.amazon.co.uk	Issue 157, p26	£519
	27in 4K G-Sync monitor	Asus ROG Swift PG27AQ	www.scan.co.uk	Issue 151, p42	£735
	34in ultra-wide curved G-Sync monitor	Asus ROG Swift PG348Q	www.ebuyer.com	Issue 157, p42	£999











Peripherals

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Mechanical gaming keyboard	Cooler Master MasterKeys Pro S (Pro L version recommended if you need a numeric keypad)	www.box.co.uk	Issue 152, p44	£100
	Premium mechanical gaming keyboard	Corsair Gaming K70 RGB Rapidfire	www.box.co.uk	Issue 154, p21	£149
	Budget gaming mouse	Cooler Master Xornet II	www.box.co.uk	Issue 149, p28	£19
	Gaming mouse	Logitech G402 Hyperion Fury	www.scan.co.uk	Issue 139, p53	£50
	Ambidextrous gaming mouse	Roccat Kova	www.box.co.uk	Issue 150, p28	£45
	MMO gaming mouse	Corsair Scimitar RGB	www.box.co.uk	Issue 150, p17	£60
	Wireless gaming mouse	SteelSeries Sensei Wireless	www.box.co.uk	Issue 139, p61	£106
	Steering wheel and pedals	Logitech G920 Driving Force UPDATED	www.currys.co.uk	Issue 159, p55	£180

Audio

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	PCI-E sound card	Asus Strix Raid DLX	www.scan.co.uk	Issue 148, p28	£162
	2.1 speakers	Acoustic Energy Aego M	www.amazon.co.uk	Issue 142, p52	£139
	Soundbar	Razer Leviathan	www.overclockers.co.uk	Issue 142, p57	£200
	Headset	HyperX Cloud II	www.scan.co.uk	Issue 142, p46	£66
	Surround-sound headset	Asus Strix 7.1	www.overclockers.co.uk	Issue 142, p43	£175

Systems

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Quiet gaming PC	Scan 3XS Z170 Vengeance	www.scan.co.uk	Issue 151, p60	c.£1,500
	Dream PC	Scan 3XS Barracuda	www.scan.co.uk	Issue 145, p58	c.£9,499
	Sub-£2,000 gaming PC	Scan 3XS Z170 Vengeance 1080 GL	www.scan.co.uk	Issue 155, p62	c.£1,950
	Mini-ITX gaming PC	CyberPower Hyper Liquid 100	www.cyberpower-system.co.uk	Issue 158, p60	c.£1,999
	Premium mini-ITX PC	Overclockers 8Pack Asteroid	www.overclockers.co.uk	Issue 154, p56	c.£3,990
	Premium PC	Scan 3XS X99 Carbon Fluid GL SLI	www.scan.co.uk	Issue 156, p64	c.£4,100
	Water-cooled PC	Overclockers Infin8 Toxicity	www.overclockers.co.uk	Issue 150, p58	c.£3,414
	4K gaming PC	Scan 3XS X99 Carbon X SLI	www.scan.co.uk	Issue 158, p64	£4,500
	High-performance gaming laptop	Scan 3XS LG17 Carbon Extreme UPDATED	www.scan.co.uk	Issue 159, p30	£2,550
	Thin and light gaming laptop	Scan 3XS LG15 Vengeance G-Sync	www.scan.co.uk	Issue 153, p51	c.£1,480

Games



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RICK LANE / INVERSE LOOK

TEARING UP THE SCRIPT

Narrative ambiguity can make for fascinating virtual storytelling, but only when there's a story in the first place, argues Rick Lane

Storytelling is one of the trickiest parts of game design. What makes gaming an interesting art form – interactivity, dynamism and unpredictability – is at odds with modern storytelling conventions, where plot, pace and character are guided with expert detail by an authorial hand. It's like putting on a play where the audience is on stage with you – a drunken audience that's more interested in kicking over the props and poking the actors than listening to them warble about existence or relationships.

Games have previously grappled with this problem by adopting one of three approaches. Games such as *Half-Life* embrace linear storytelling, funnelling you along a scripted path and using momentum to keep you interested. Others, such as *Mass Effect*, lend you agency through a branching narrative, where your choices affect the story's path. Lastly, games such as *Crusader Kings* don't have a fixed story, but can produce hundreds of unique stories through a combination of their systems and the way you interact with them.

More recently, however, a fourth method has evolved, which doesn't tell the story at all. Instead, the story is broken up into hundreds of tiny shards and sown through the game world, waiting for you to find them and, if you choose, attempt to piece them back together. It's a method pioneered by the brilliant *Dark Souls*, where the history of the realm of Lordran, and your role within it, is divulged piecemeal by cryptic item descriptions, the riddling exhortations of Lordran's inhabitants and the imagery of the game world.

In effect, the story becomes a puzzle. The beauty of *Dark Souls*' storytelling isn't merely in how it breaks up the story, but how it uses lyrical prose and narrative ambiguity to create gaps and

uncertainties that can only be filled by your imaginative deductions. It's an effective method of threading a story through a game, making it highly interactive, while also allowing for, and indeed encouraging, intelligent and playful writing.

Not surprisingly, several games have since minimised explication in favour of more ambiguous storytelling. We reviewed two examples last month – the delightful underwater exploration game *Abzu*, and *Playdead*'s not-a-sequel-honest-to-*Limbo*, *Inside*. But there's a crucial difference between the way these games approach narrative ambiguity and *Dark Souls*' approach. Beneath its surface, *Dark Souls*' story is deeply layered.

You can pass it by without noticing, but there's an abundance of information to find if you actively look for it. There's no such depth to *Abzu* or *Inside*. They produce narrative ambiguity simply by having minimal narrative in the first place.

It's an important distinction. It's easy to create a sense of mystery when you offer the player little information, and while those equivocations may initially seem clever, the experience is ultimately shallow and unsatisfactory. It's quite different to offer a player all the information they require, yet still retain a level of uncertainty. *Her Story* is another fantastic example; a detective game where all the information is at your fingertips, but it's fragmented within a computer archive, and communicated to you through a deeply unreliable witness.

The key difference is that *Dark Souls* and *Her Story* use ambiguity as a means to tell the story, whereas ambiguity is both the means *and* the end in *Abzu* and *Inside*. As more games adopt this storytelling method, it's important to be able to tell whether the game's narrative has genuine substance, or whether it's an empty vessel under the guise of art. **GPC**

It's easy to create a sense of mystery when you offer the player little information



Deus Ex: Mankind Divided / £40 inc VAT

DEVELOPER Eidos Montreal / PUBLISHER Square Enix / WEBSITE www.deusex.com



After the enormous success of Human Revolution, the golden-hued prequel that proved it was possible to make Deus Ex great again, a sequel to the prequel was inevitable. The mainstream games industry can't let a sleeping Aug lie when there's money to be made. Yet sequels are treacherous ground in the Deus Ex world, as demonstrated by the disappointing follow-up to the Ion Storm original. Deus Ex: Invisible War shot for the moon, missed, and flew right into the roiling surface of the sun instead.

Mankind Divided mercifully avoids the fate of Invisible War, but it does so in a manner that isn't characteristic of Deus Ex – playing it safe. The sequel to Human Revolution is the least adventurous entry in the series. It's both smaller and messier than Human Revolution, and stumbles in the few instances where it does step out of its older sibling's shadow.

While it's a smaller and shakier ride, though, the latest Deus Ex remains a fun one. Mankind Divided takes place two years after the climax of Human Revolution, where a device was set off that caused all augmented people in the world to turn uncontrollably violent. This event, colloquially referred to as 'The Incident', has resulted in segregation between normal people and those infused with performance-enhancing augmentations. Behind the scenes, multiple factions vie to take advantage of the social schism to further their own nefarious ends, and it's up to our gravel-voiced, chisel-armed protagonist Adam Jensen to unravel the nest of conspiracies that surround mankind's divide.

This time, the action is centred on Prague. Once a happy home to both Augs and humans, the capital of the Czech Republic is now a hive of suspicion and fear. Augs and humans travel on separate metro trains, while street intersections are patrolled by an increasingly



oppressive police force, with high-tech armour and hulking mech suits gleaming with the fundamental hypocrisy of anti-Aug sentiment.

Although the developer's surface portrayal of a fictional apartheid is convincing, it's ultimately window dressing. The social issues at the heart of the divide aren't really investigated through the story or the act of play. The narrative theme of segregation is merely a means to a plot, and the game is fundamentally about exploring spaces rather than races. Its exploration of social prejudice extends to overheard conversations, graffiti on the walls and repetitive cutscenes in which policemen check your papers with barely concealed contempt.

Part of the problem is that, despite the semantics, Mankind Divided is very inward-looking. Prague isn't simply your base of operations, but the focus of around 90 per cent of the action, with no alternative city hub and only brief excursions to other locations. Consequently, we don't see the wider picture. Similarly, despite being discussed in exhaustive detail, the conspiracy at the centre of Mankind Divided lacks the grandeur of the original game and that of Human Revolution. Aspects of the presentation don't help

OVERALL SCORE

80%

/ VERDICT

Robustly made and immersive, but lacking the grand scope and thought-provoking narrative that made Deus Ex such an enduring classic.

this lack of urgency. Some of the voice acting is flatter than a burst tyre on Jupiter, and conversations are fragmented by interminably long pauses while the game spools up the next line of dialogue. Characters are surprisingly shallow too, often either po-faced straight men or zany, one-dimensional quest dispensers that jar uncomfortably with the game's broader atmosphere.

On a visual level, though, *Mankind Divided* is a tremendous achievement. Each scene is dense with stunning architecture and dozens of meticulously designed objects. The Interpol office where Jensen works is a prime example, being a bustling hive of litter-strewn desks and flickering neon screens that resembles a busy stock-trading floor. The entire game feels 'lived in' – it's less cyberpunk and more clutterpunk.

Prague is also a fantastic space to explore, being complex in design and rich in detail. The more colourful palette and blending of old stone architecture with futuristic designs is a big improvement over *Human Revolution*'s sickly sepia aesthetics, carrying notes of *Dishonored*'s beautiful city of Dunwall. From the rooftops to the sewers, it's littered with secrets, side-quests and, most importantly, pathways to progress.

Mankind Divided might be flawed, but it understands *Deus Ex*'s greatest strength – choice, and offers it in abundance. Each mission, regardless of its significance, offers multiple ways to reach your objective, whether it's carving through your enemies with guns and arm chisels, stealthily avoiding detection by using quiet non-lethal attacks, or using your skills and the environment to circumvent combat entirely.

To these ends, Adam Jensen's already impressive skillset is expanded with roughly twice the number of augmentations. A new vision mode strips back the environmental detail and highlights enemies and points of interest such as ventilation shafts and computer terminals, enabling you to quickly and effectively plan your route. A *Dishonored*-style blink ability allows Jensen to dash forwards short distances undetected, handy for slipping past enemy patrols. By far the strangest new ability is a powerful air-cannon that can knock multiple targets off their feet, setting them up for an easy dispatch.

Mankind Divided also features some of the best scenarios seen in *Deus Ex*. The Palisade Bank is a gleaming temple of financial futurism, requiring surgical precision to slice through its clean lines and watertight security.

At the other end of the spectrum is a tenement block controlled by a religious cult. The crumbling masonry, tight stairwells and ramshackle scaffolding poses a formidable vertical challenge.

Yet by far the standout mission takes place in Golem City. A towering shanty town that acts as an Aug ghetto, this huge mission includes its own explorable mini-hub wherein Jensen must infiltrate a gang of Aug rebels and extract their



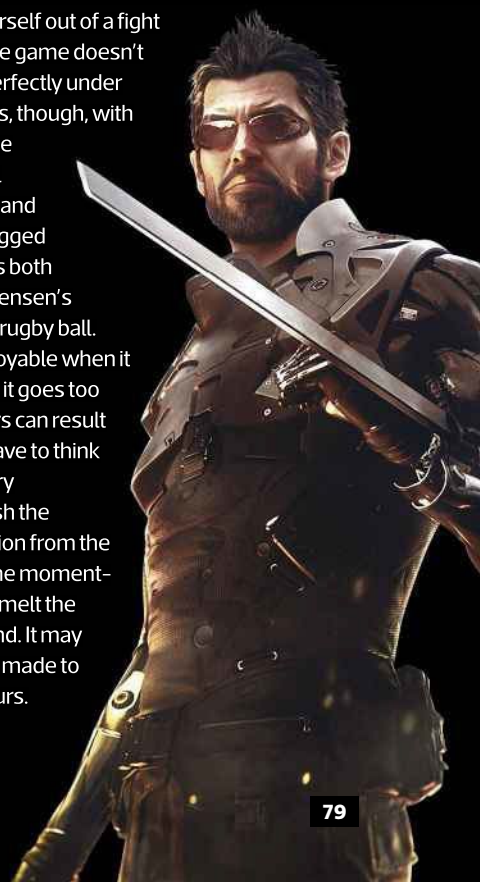
leader for interrogation.

One important improvement is that boss fights are no longer combat-focused. Now any approach will work – even talking yourself out of a fight entirely. The game doesn't respond perfectly under your fingers, though, with

some bizarre design choices blemishing the experience. Performing a melee attack still triggers an immersion-breaking cutscene, and dead or unconscious bodies have to be dragged around rather than carried – a system that's both cumbersome and nonsensical, given that Jensen's carbon-fibre arms can throw a fridge like a rugby ball.

However, *Mankind Divided* is hugely enjoyable when it plays to its strengths. In fact, in some ways, it goes too far. The sheer abundance of options it offers can result in the game being too easy, as you rarely have to think on your feet, or adopt a secondary or tertiary approach. *Mankind Divided*'s refusal to push the series' boundaries also results in a regression from the brilliance of *Human Revolution*, although the moment-to-moment play is entertaining enough to melt the game's larger problems into the background. It may not be a classic, but it's still sufficiently well made to sustain a fan of the series for a good 30 hours.

RICK LANE





Grow Up / £7 incVAT

DEVELOPER Ubisoft Reflections / PUBLISHER Ubisoft Reflections / WEBSITE www.ubisoft.com/en-GB/game/grow-up



OVERALL SCORE

90%

/ VERDICT

Grow Up offers everything you could want from a sequel to Grow Home, including an open world, although it lacks the bottled-lightning feel of the original.

Grow Home was the surprise hit of 2015. This delightful little game focused on a cute robot called BUD and his mission to retrieve a seed from the gigantic, atmosphere-prodding Star Plant, with innovative climbing mechanics and a joyous sense of adventure. Just 18 months later, we already have a sequel but, despite the worryingly brief turnaround time, Grow Up is substantially larger, and it executes its expanded ideas with a similarly exuberant quality.

This time, BUD's mission is to rescue MOM, whose chunks are scattered across a planet's surface after a high-speed collision with said planet's Moon. If that last

sentence has you concerned, bear in mind that MOM is a spaceship. In order to escape the planet, BUD must retrieve all the pieces of MOM, then ascend to the Moon to piece the ship back together.

The most significant change from Grow Home is structure. While Grow Home offered opportunities to explore, it had a fairly linear focus on the ascent of the Star Plant's giant stalk. Grow Up, on the other hand, has an open world that allows complete freedom of exploration.

The pieces of your spaceship can be collected in any order, be it from cactus-strewn deserts or strange mushroom forests. There are several Star Plants that yearn



ReCore / £30 incVAT

DEVELOPER Armature Studio and Comcept / PUBLISHER Microsoft / WEBSITE www.recoregame.com



OVERALL SCORE

55%

/ VERDICT

Smartly written and elegantly presented, but ReCore's beauty is ultimately skin-deep.

ReCore's heart lies with the likes of Zelda, Metroid Prime and other 3D Nintendo classics, but it's a modern open-world game with all the messy, extraneous clutter such an arrangement entails. You play Joule, an engineer posted to the neophyte human colony on the desert planet Far Eden. Joule awakes from a lengthy cryosleep to find the colonisation efforts are sorely behind schedule. Many of the colonists who arrived in the first wave are missing, while the robots designed to aid the colonisation efforts have become corrupted. It's up to Joule and her trusty robodog Mack to find out what went wrong and save the colonial mission.

Despite the arid landscape and dark edge to the plot, ReCore tells a bright and breezy story. Joule and Mack are an immediately likeable duo, the writing is sharp and the plot has purposeful, forwards momentum. Meanwhile, the world of Far Eden is an inviting place to explore. The barren landscape has an eerie beauty, home to strange rock formations, pummelling dust storms and the wreckage of both modern and ancient technology.

Not surprisingly, ReCore is at its best when you're exploring, whether you're clambering along rock faces



using Joule's double-jump and dash abilities, delving into one of the game's many 'dungeons' to retrieve special robot cores and other artefacts, or simply soldiering on to the next story mission while Joule and Mack chat to each other. It's a game with real personality, and a sense of adventure from which many of its peers could learn.

If ReCore focused on these elements, you'd be reading a glowing review, but it sadly suffers from severe padding. It's filled with repetitive fetch quests and arbitrary game-lengthening exercises, whereby it asks you to find three



to be climbed, alongside new abilities to be collected and optional challenges.

Ubisoft games have a tendency to revert to the same open-world model, filled with cut-and-paste activities, and *Grow Up* is no different, but the feeling is negated by the fact that *Grow Up*'s world is so much fun to traverse. The grip-based climbing mechanic makes a welcome return, enabling BUD to quickly ascend vertical surfaces via alternate presses of the mouse buttons or pad triggers. Early on, BUD also acquires a jetpack that enables short bursts of flight. It can be combined with an airbrake, and later a glider, making it easy to hop between the dozens of floating islands hovering above the planet's surface.

Another new feature is BUD's ability to collect and grow plants anywhere in the game world. There are around two dozen unique plants, which can aid BUD's movement by offering new climbing surfaces, bounce-pads, catapults and so on. Sadly, most of them are variations on three or four themes, though, so this idea quickly loses its novelty.

It's a minor flaw in an otherwise wonderful and surprisingly substantial game for both adults and children. It doesn't quite wield the same innovative magic as *Grow Home*, primarily because it isn't BUD's first rodeo, but the larger world makes up for it and *Grow Up* still possesses charm in spades.

RICK LANE



items, each one requiring you to find three *other* items to retrieve it, and so on.

It's also quite combat-heavy, but the combat isn't very good. It has some interesting ideas, such as a colour-coding system where switching your ammunition to match an enemy's colour does extra damage, and a neat finishing move that involves playing a little game of tug-of-war to pull the power core out of an enemy robot. The enemy designs are also impressive, particularly the end-of-dungeon bosses. Yet this effort is ultimately for naught

because the combat simply doesn't feel right – both Joule's movements and weapons have a rattling hollowness.

In addition, the game's main selling point, the three robot companions, barely feature during play. They're essentially relegated to a special move you can execute in combat, and their underwhelming presence undermines the extensive crafting system, which relates entirely to your undercooked mechs. *ReCore* is likeable enough on the surface, but it lacks the substance needed to be worth your time.

RICK LANE

Virginia / £15 inc VAT

DEVELOPER Variable State / PUBLISHER 505 Games /

WEBSITE <http://variablestate.com>

Virginia is a first-person thriller that's heavily inspired by TV dramas such as *Twin Peaks* and *True Detective*, and this televisual inspiration is both its strongest asset and greatest failing. Its colourful art, filmic editing and *fantastic* musical score powerfully evoke the aforementioned TV shows at least on a surface level, but it misses the point of those shows entirely.

You 'play' FBI agent Anne Tarver, who is assigned two simultaneous investigations at the start. Tarver is sent to the town of Kingdom, Virginia, to look into the mysterious disappearance of a local boy. At the same time, she conducts an internal investigation into her partner on this case, Agent Maria Halperin, who is suspected in the theft of several files from the FBI's archives.

The developers make several intriguing creative decisions in the telling of the story. Firstly, there's no dialogue, either written or voiced. Instead, the game relies on visual communication, be it through characters' facial expressions and gestures, or through text such as signs, leaflets, case files and so on. The game's other trick is the aforementioned filmic editing. Virginia only ever stays on one scene long enough to communicate what's happening. You sit opposite the FBI's director as he assigns you the case, then there's a jump cut to you travelling in the car with Halperin, which cuts again to you interviewing the parents of the missing boy.

Initially, these two ideas work well, lending an additional layer to the mystery as you attempt to work out what's happening in each scene, via what's communicated. But as the story grows more complex, it becomes a barrier to comprehension. Towards the end, as reality gives way to more fantastical elements – dreams, visions, and premonitions of the future – the plot becomes almost impossible to follow, like trying to solve a hedge maze after stepping out of a centrifuge.

But what's infuriating about Virginia is that the player is always kept at arm's length. Interactively, you're limited to walking around certain scenes, and clicking on one or two



objects. That's it. It's like watching a DVD that randomly pauses for no particular reason. Virginia is so interactively barren that it's difficult to fathom why it's a game at all.

Virginia's biggest flaw, however, is that it misunderstands the appeal of shows such as *Twin Peaks*, which immerse you in a specific place and time. They take time to familiarise you with locations and characters, so you can imagine eating cherry pie in the Double R Diner. What you want from an equivalent game is a *Twin Peaks* you can explore. Instead, Virginia is a highlight-reel of a place you don't care about. The soundtrack is genuinely superb, but that's about it.

RICK LANE

OVERALL SCORE

30%

/ VERDICT

There's an enjoyable film somewhere inside Virginia, but it's bafflingly disappointing as a game.





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RICK LANE / THE ENGINE ROOM

Dawn

Rick Lane shines a light on the stunning engine that powers Deus Ex: Mankind Divided

Back in 2011, Eidos Montreal released Deus Ex: Human Revolution to both critical and commercial success. Human Revolution was the culmination of four years of hard work, pushing technology to the very edge of its limits. The CDC engine, developed by Crystal Dynamics for 2007's Tomb Raider: Anniversary, proved not entirely suited to a game as large and complex as Deus Ex.

'In the last year of the production of Human Revolution, iterating over that content was proving difficult,' says Julien Bouvrais, chief technology officer of Eidos Montreal 'We were overall quite happy with the runtime of the engine and how we could shape it to bring the art direction to life, as well as create the gameplay elements that make up the game. The CDC engine was a great engine for quickly creating new game features. But on the other hand, the workflows were painful.'

Once Human Revolution was wrapped up, the first order of business for Eidos was to figure out the best tech system for the sequel. Part of the team began overhauling CDC, while another part searched for potential alternatives. Eventually, the team homed in on Glacier 2, IO Interactive's engine initially built for Hitman: Absolution. 'It was definitely not an easy decision,' says Bouvrais. 'Many programmers liked that CDC was easy to learn – adding new features was relatively quick and runtime performance was really good. However, being able to quickly iterate over content creation was the key deciding factor.'

For a while, Glacier 2 became the new Deus Ex engine. Eidos and IO even collaborated on its development, adding universal



Dawn is the first engine to be developed specifically with Deus Ex in mind

Mankind Divided boasts four times the number of NPCs seen in Human Revolution



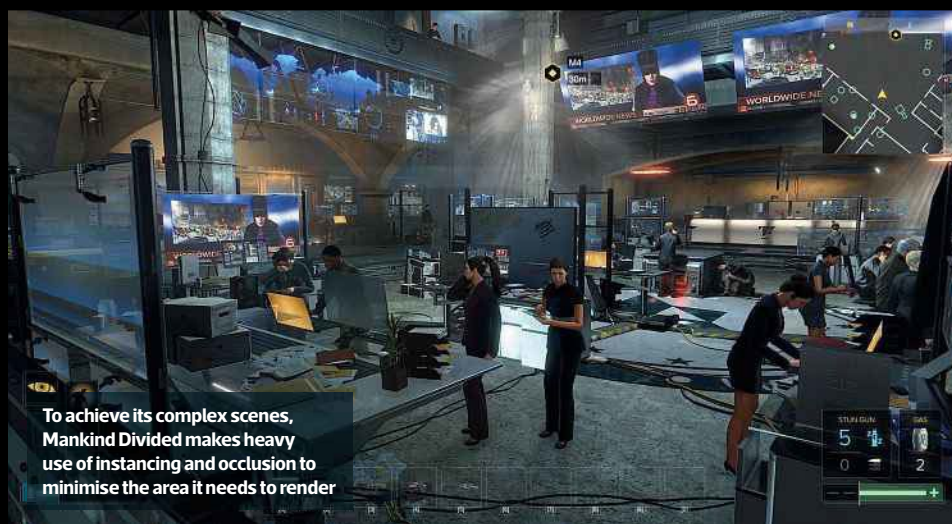
features such as 64-bit support and switching the rendering pipeline to a physically based system. But soon Eidos began tailoring its own version of Glacier 2 specifically towards Deus Ex. 'We reworked how game assets are streamed in, added a new conversation toolset, invested in environment awareness required for player navigation and so on,' says Bouvrais. In the end, Eidos Montreal's Glacier 2 became distinct enough to warrant a new name.

And so, the Dawn engine was born – the first engine developed specifically with Deus Ex in mind.

The original Deus Ex ran on the first Unreal engine, while Invisible War used Unreal Engine 2.

Dawn also makes Mankind Divided the first Deus Ex game to be a true graphical powerhouse. One of Dawn's most impressive features is simply its ability to render an immense number of objects in any given scene.

The offices of Mankind Divided's Interpol are littered with papers, files, coffee cups and computer wiring, while the streets of Golem City are strewn with rubbish and detritus. The effect is so convincing



To achieve its complex scenes, Mankind Divided makes heavy use of instancing and occlusion to minimise the area it needs to render

that it edges beyond realism into its own aesthetic style.

'The art direction of Deus Ex revolves around a heavy amount of details and this has created lots of challenges,' Bouvrais explains. 'We make heavy use of instancing to allow for a high amount of clutter in many of the environments, which helps to keep the memory footprint under control. This high level of detail also ended up creating a lot of aliasing due to the high frequency nature of the environments. We tried different solutions and ended up selecting a temporal anti-aliasing algorithm, which worked particularly well.'

Such a level of detail also demands a flexible and precise lighting system, especially as Mankind Divided regularly and seamlessly transitions between indoor and outdoor environments. As with the level instancing, the lighting relies heavily on targeting the scene the player sees. 'We use a tiled deferred renderer with 8x8 tiles, but start with a broad phase culling pass on 64x64 tiles to select the lights that will end up shading the rendered tiles,' says Bouvrais. 'The player navigates in mixed indoor/outdoor environments, so we took care to avoid indirect light bleeding from indoors to outdoors and vice versa.'

Mankind Divided also adopts the PureHair technology seen in Rise of the Tomb Raider, and couples it with a new system called PureMaterial. Both technologies are created by publisher Square Enix's R&D department named Labs.

'Labs was created around three years ago, and is set up slightly differently from your classic R&D group,' says Bouvrais. 'It works closely with the game team to



The lighting in Deus Ex goes through various phases to create a rich, layered look

deliver a working feature that's tailored to the requirements of each particular game.'

PureMaterial is designed to replicate the look of textured surfaces, such as metals and fabrics. This tech includes a take on parallax occlusion mapping, which creates the illusion of 3D definition on a surface using a displacement map, rather than rendered geometry.

Mankind Divided's multi-path approach also presents a challenge, requiring a vast number of developed assets that many players will never ultimately see. To this end, Dawn inherited a useful new feature from IO's Glacier 2 called the Entity system, which helps developers to visualise the behaviours of objects and create new ones.

'It's basically a node-based system embedded in the core of the engine that opens up many functionalities

One area where Dawn falls down is body and facial animations, which Eidos Montreal plans to fix



to content creators. One can create new behaviours by aggregating base nodes,' Bouvrais explains.

'It's not a new concept, and it's been seen in other engines, of course, but this system is part of the root architecture. A lot of the tools we created for Deus Ex are built on top of it. Our scripting system is a prime example.'

Mankind Divided also saw considerable improvements to the

AI over Human

Revolution. The AI now automatically detects cover, rather than relying on developer-designated cover spots. They work together in groups to support each other, and can match the player's abilities, including using Augmentations. 'We also have four times the number of NPCs, enabling us to create a

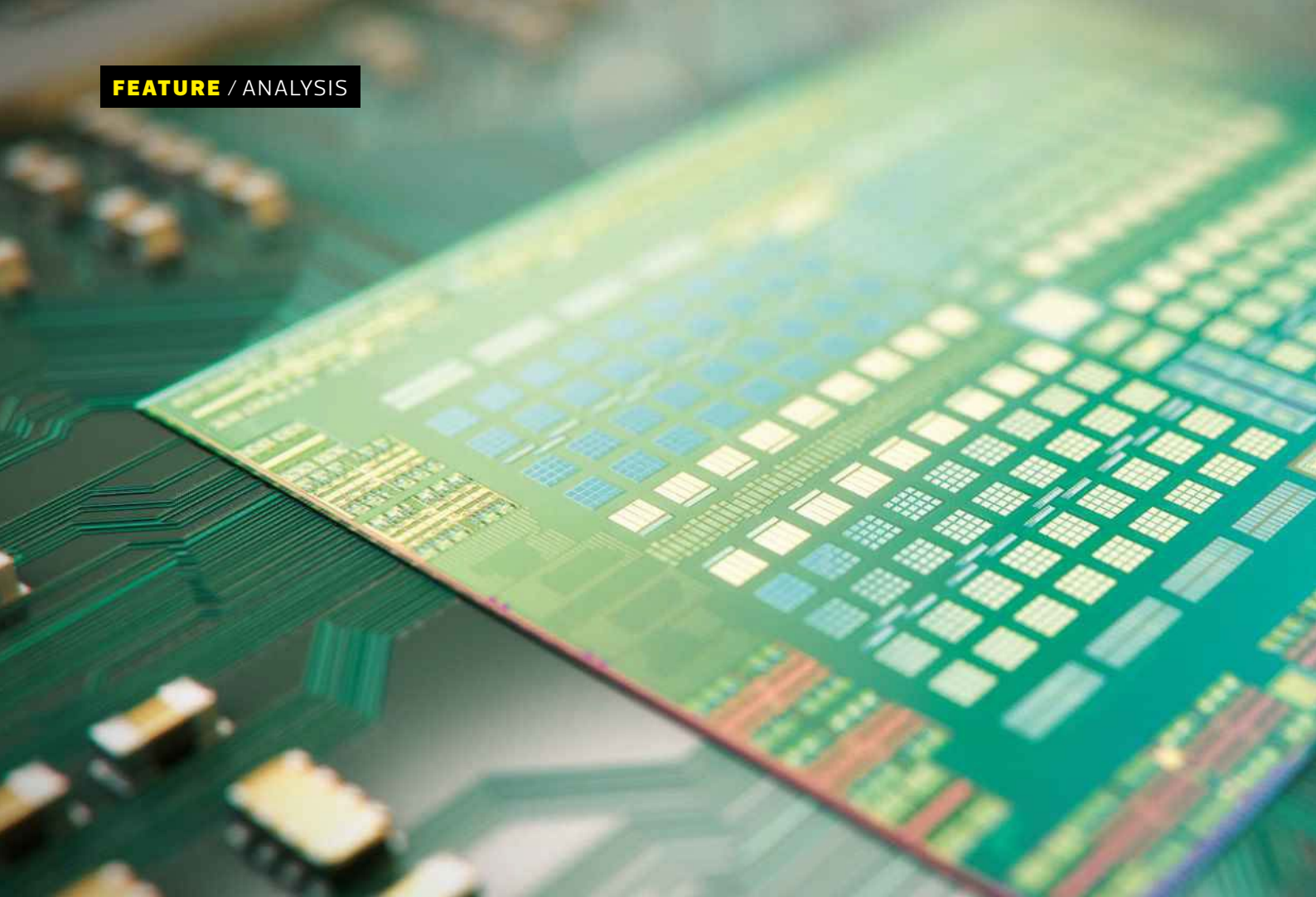
richer experience,' says Bouvrais.

With Mankind Divided now released, Eidos Montreal is once again taking stock on how its tech has performed. This time, however, the focus is on improving the current tech rather than creating a new engine. One of the most noticeable issues with Dawn is its stiff and angular character animations. 'Our animations are well below where we would like them,' Bouvrais says. 'Our studio is really about creating games with strong characters and deep stories, so having believable motion is a huge part of delivering the narrative aspect of the game. The Labs team is currently working on exciting new tech both for body and facial animation.'

Other major areas for development include material creation, better particle effects and, curiously, iteration times.

'While Dawn is very powerful, the learning curve is quite steep and we're not where we would like to be,' says Bouvrais.

Nevertheless, he's extremely optimistic about the engine's future. 'Mankind Divided was released just one month ago, but the version of Dawn Engine with which we're currently working is already quite an improvement,' he says. **CPC**



INSIDE THE GPU

DON'T KNOW YOUR TMUs FROM YOUR GPCs? EDWARD CHESTER DELVES UNDER THE HOOD OF THE LATEST GRAPHICS CARDS TO EXPLAIN HOW THEY WORK

In theory, buying a graphics card is simple. A quick glance at some reviews reveals the level of performance any given card provides – cross-reference that information with your budget and you should be able to narrow down your choices to one or two cards.

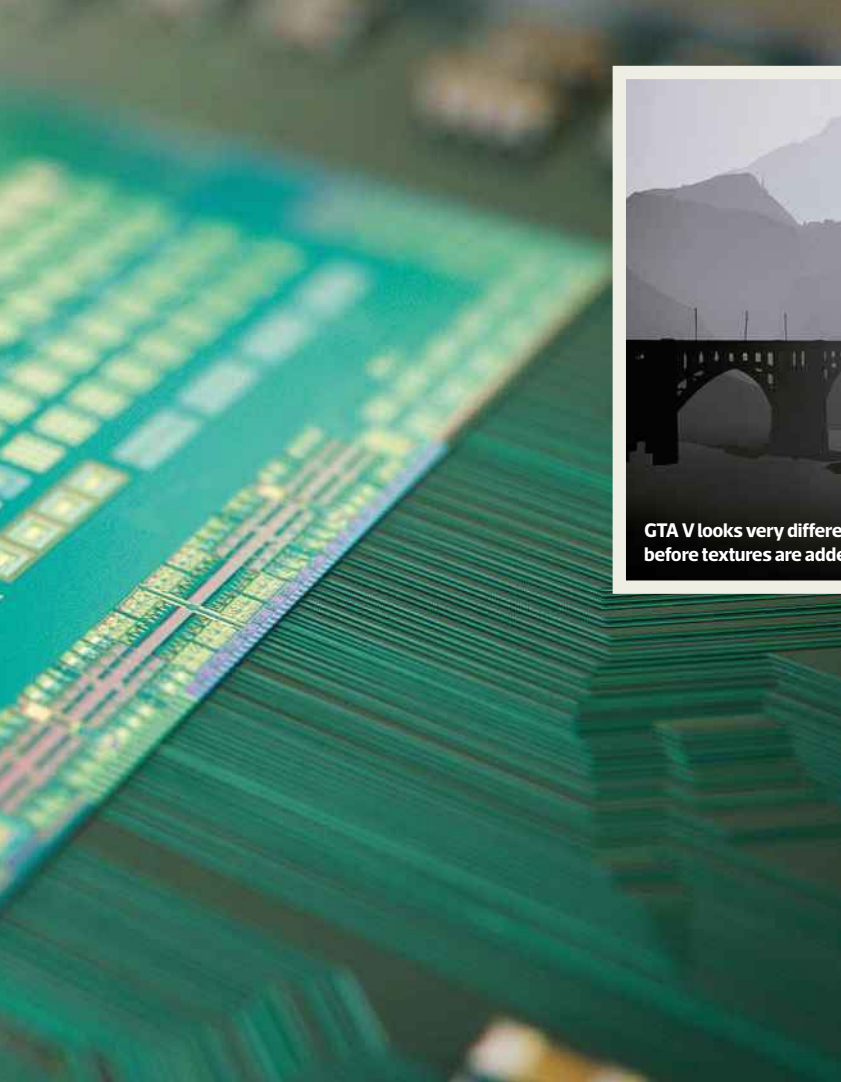
However, the reality is that GPUs can quickly get confusing, with many complicated terms, and a review may leave you with more questions than answers.

So, to help out, over the next few pages we're going to give you a complete overview of a graphics card's workings. Throughout this article, we'll use the Nvidia GeForce GTX 1060 and AMD Radeon RX 480 as comparative examples, as they represent the most current offerings from both companies that are price and performance comparable.

THE GRAPHICS PIPELINE

The key to understanding what a graphics card does is to understand the graphics pipeline itself. A pipeline is simply any sequence of data processing elements where the output of one element is the input for the next. In the case of computer graphics, it's the sequence of computing processes needed to take a 3D scene from being a bunch of points in a virtual 3D space to a 2D picture on a screen. It can be broken down into a handful of main steps, but let's start by discussing how 3D scenes are assembled.

The core principle is that each object in a 3D world – from tanks and teacups to the terrain – is described by a series of polygons (almost always triangles or rectangles). These



polygons make up the outer surface of the object and can be defined by a sequence of numbers that corresponds to the XYZ coordinates of the corners of each polygon – these are called its vertices. Put together loads of objects in a scene and you'll have thousands or even millions of polygons describing that game world. Then add colours, lighting, textures, effects and so on, and you'll build up layers of detail until you've eventually created a whole scene.

The first step in the pipeline is to transfer the vertices of all those individual models from the co-ordinate system of the model (the centre of the model is its origin) to the co-ordinate system of the game world (which has its own origin). This might be done many times if you have, for example, many identical trees in one scene.

Next, all those same vertices are transformed again so that they're described relative to the view of the player (camera). And finally, another transformation is required to account for what we see from a human perspective.

At this point, we've completed positional calculations on the vertices so we could render the scene, and it would appear as a mass of dots that roughly looks like what you want. The next job is to give those vertices some life. First, the vertices are given colour and lighting attributes via vertex shading and lighting functions, and textures can also be applied to the vertices.

Textures are 2D images that are placed over the wireframe of a 3D model to give it detail – it's the primary means of adding colours and details to modern games. However, at this stage,

we're not completely skinning the model but only defining where the vertices will land on the texture.

Next, we can optionally apply some geometry shading. This is where extra geometric detail can be added to a model to create smoother-looking curved edges or bumpy surfaces via tessellation. Adaptive tessellation also allows you to vary the geometric detail based on the distance of the object from the camera – if it's close, you'll add detail, if far away, you might reduce it. Those vertices are then joined up into what are called primitives. These are either triangles, lines or dots and, in essence, they recreate the wireframe model that the vertices originally described.

At this stage we can start ditching data to save some processing time. For instance, back-face culling will throw away primitives that aren't facing the player. We're then ready to transition all those primitives from a 3D space to one that

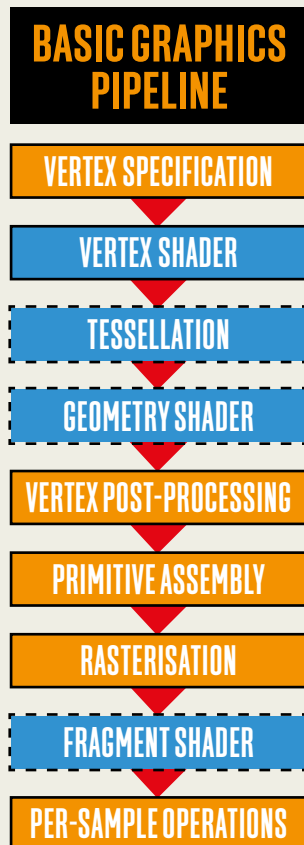
corresponds to the 2D grid of pixels that is your screen. This process is called rasterisation.

The result is that each triangle is not now defined by three points and the space between them, but a series of individual dots that fill that space. Each of these dots is known as a fragment and, as well as being a point in space that corresponds to a pixel, it's also given a host of other characteristics that are interpolated from the original vertex values. These characteristics include colour, lighting, texture location, depth relative to the screen, transparency and normal (a direction perpendicular to a surface that's used for calculating lighting effects).

All of this data is then passed to the pixel or fragment shader stage of the pipeline. Here, all manner of extra processes may be applied to the fragments to add extra visual effects. Examples include further lighting and surface effects, such as bump mapping, texture manipulation and much more. Once all this fragment processing has been done, it's finally time to put all the information together and create the final pixels, which is done in the render output unit or ROP stage.

Put simply, the ROP stage takes all the fragments and adds them up. For example, you may have data for multiple fragments corresponding to the same pixel – one fragment might represent translucent smoke, the next a tinted glass window and the next the blue sky. The ROP will add all these fragments together until it comes up with a final value for that

pixel. It's also here that any anti-aliasing is performed. Once calculated, the complete image, or frame, is passed into the frame buffer where it's ready to be drawn to your screen.



HOW MODERN GPUs WORK

Now that we've established the overall picture of what's needed to convert a 3D world in your computer to a magnificent 2D image on your screen, let's move to the next question – just how does that process map to what's in a GPU?

Well, back in the day, it was much more straightforward, as graphics processors corresponded directly with key steps in that pipeline. You had vertex shaders, pixel shaders, texture units, rasterisers and so on.

However, around the launch of DirectX 10, pixel and vertex shaders were combined into a unified shader architecture. With this move came the ability to also use the shaders – now called stream processors – to perform more general parallel computing tasks, which makes GPUs much more flexible, but it also makes them a little harder to map to the graphics pipeline.

STREAM PROCESSORS

At the heart of a modern GPU is a collection of tiny processing cores called stream processors. By combining hundreds or thousands of these processors, you can power through highly parallel workloads, such as applying colours to vertices or calculating the normals of many fragments.

These stream processors do the majority of the grunt work in a GPU, with most other components serving to feed them tasks and data in an organised manner. However, simply comparing the number of stream processors between AMD and Nvidia cards tells us very little, because they're built so differently – the Radeon RX480 has nearly double the stream processors of the GTX 1060, but is often slower.

The only vaguely useful indicator that's often quoted is the theoretical number of floating point operations per second they

can achieve, measured in GFLOPs. Here, the RX 480 is still faster but only by 34 per cent.

VERTEX SHADING

Before data can be processed by those stream processors, it has to be set up, organised and distributed, which is where the 'front end' of a GPU comes in. This part of the GPU includes an overall command processor (Graphics Command Processor for AMD; Gigathread Engine for Nvidia) that will pull in data from system memory, copy it to VRAM and then distribute the workload to the GPU's other components.

Once ready, the data is passed to the bank of stream processors for vertex shading. After all shading, lighting and texture processing has been performed for that batch of vertices, the GPU will pass on that data for geometry processing or rasterisation.

TEXTURE PROCESSING

During the vertex processing stage, textures can be mapped to vertices, with the textures being set up by dedicated hardware called texture mapping units (TMUs). The important number here is not how many TMUs there are, but their texture fill rate – for the GTX 1060, we have 80 TMUs for a texture fill rate of 156.6 gigapixels/sec while the RX 480 has 144 TMUs for a fill rate of 161.3 gigapixels/sec. Texture fill rate is one of the few numbers that will give you a reasonably direct comparison between AMD and Nvidia cards, and it can be an important indicator of performance.

GEOMETRY SHADING

Geometry shading is an optional stage in the pipeline. If a programmer chooses to perform some geometry operations



on the vertex data, a geometry setup engine will prepare the data then send it back through the stream processors to complete those operations. GPUs also have dedicated tessellation hardware.

RASTERISATION/PIXEL SHADING

After vertex and geometry manipulation has been completed, the data is sent through a hardware rasteriser to convert the stream of vertices into primitives, then into a stream of fragments. Once fragments are calculated, a z-cull will also be performed. This process looks at the relative depth of all the overlapping fragments and ditches any that are fully covered by other fragments. The stream of fragments is then fired back through the stream processors to have any pixel/fragment shading performed. This is perhaps the single most compute-intensive stage in the pipeline.

RENDER BACK END/ROPs

Once pixel shading is complete, the final image can be assembled by the ROPs, which use dedicated hardware, and there are performance numbers that can be directly pinned to them. The key measurement for ROPs is their pixel fill rate (measured by multiplying the clock speed by the number of ROPs), which is simply how fast they can write to the frame buffer (draw to the screen). The GTX 1060 has 48 ROPs that can output 72.30 gigapixels/sec while the RX480 has 32 ROPs and a pixel fill rate of 35.80 gigapixels/sec.

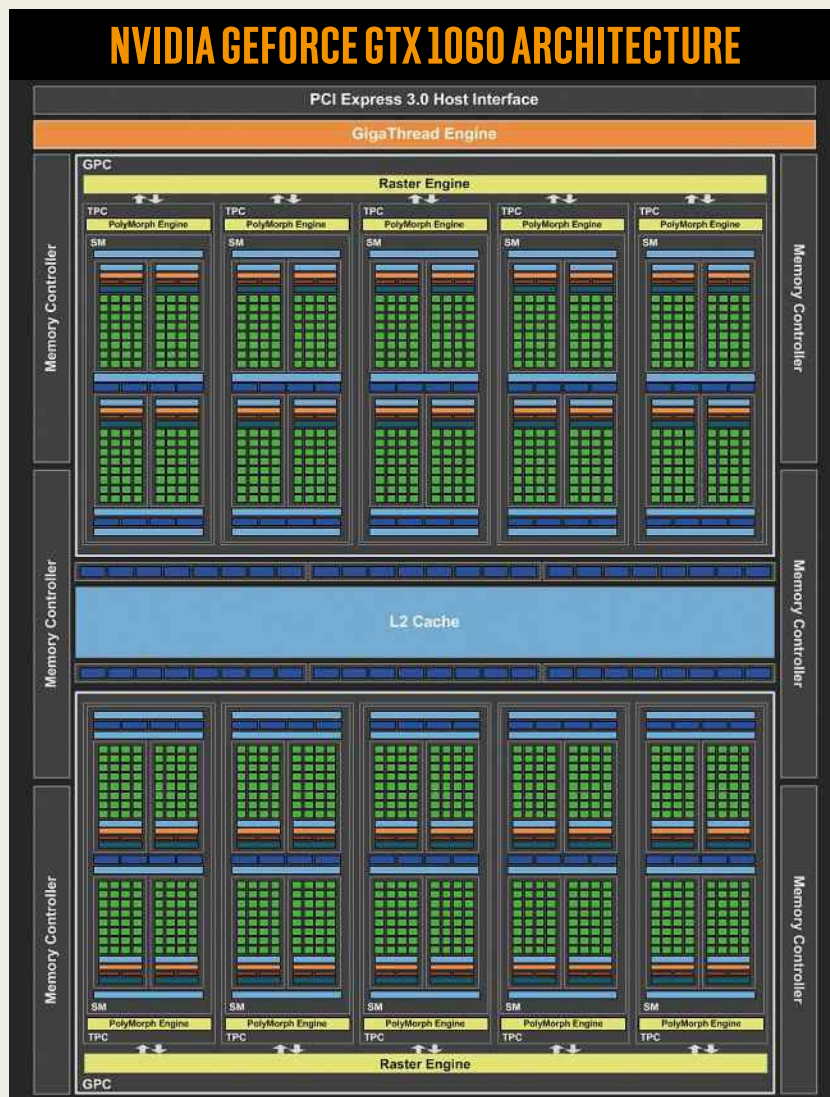
Having sufficiently fast ROPs is crucial for being able to run high frame rates at high resolutions and with high anti-aliasing. If you have fast stream processors but slow ROPs, you may be able to create wonderfully detailed-looking images, but the card simply won't be able to output the pixels fast enough.

GPCs, SMs, SEs AND CUs

To help manage the workload of all those stream processors, the GPU is subdivided into various sections. Their arrangement varies considerably between AMD and Nvidia but some of the broad concepts are the same. Working from the bottom up, stream processors are clustered together, along with TMUs, some cache memory, registers, buffers and various other hardware for managing the workflow. AMD calls these clusters Compute Units (CU) while Nvidia calls them Streaming Multiprocessors (SM).

These clusters are handed a whole packet of instructions and corresponding data (threads), and told to work through them (independently), before returning the results. These packets are called 'wavefronts' in AMD parlance and 'warps' in Nvidia lingo, with each wavefront consisting of 64 threads and each warp containing 32 threads.

Moving up a step, Nvidia combines several SMs with what it calls a Polymorph engine to create a TPC. The Polymorph engine manages vertex fetch, tessellation, viewport transformation, vertex attribute setup, and perspective correction. AMD doesn't have a strict equivalent of the TPC. Next, SMs (TPCs) and CUs are combined to create Graphics Processing Clusters (GPC) and Shader Engines (SE). These units



also add geometry processors, rasterisers and ROPs into the equation. In many ways, they're complete mini GPUs.

It might all sound rather confusing, but the crucial point is that architecting GPUs with these structures makes GPU design much easier. Rather than having to design a custom arrangement of components to optimise performance for each specific chip design, Nvidia or AMD can simply add or remove whole blocks, knowing the overall design will still be efficient and balanced. Nvidia's GTX 1070 is basically the same GP104 chip as a GTX 1080, but with five SMs disabled.

This block-based design also means that whole sections can be switched off if there are defects in the chip, without affecting how the chip manages the rest of its resources.

AMD vs NVIDIA

AMD and Nvidia implement many of the core parts of a GPU in fundamentally different ways, resulting in sometimes wildly different performance depending on what game you're playing.

The most crucial difference is between the computing cores themselves. A GPU is basically one large processor for performing Single Instruction Multiple Data (SIMD) operations – you tell the GPU to perform the same single instruction to a whole mass of data, such as making every one of a set of pixels a shade darker. This type of processing is called vector

processing. In contrast, scalar processing is where one instruction is performed on one block of data at a time.

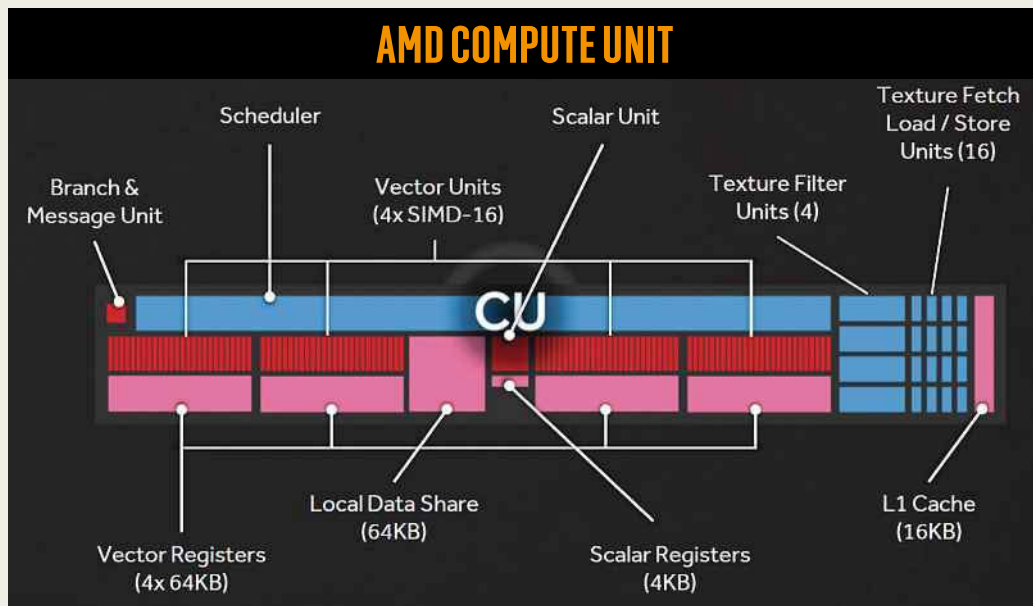
AMD has taken this vector processing to heart and arranged its stream processors into vector groups of 16. That is, they can perform a single instruction on up to 16 points of data at a time.

AMD calls these groups SIMDs. In contrast, Nvidia has chosen to keep its CUDA cores separate, with each operating in a scalar fashion. For some operations, the AMD system will be faster, but if data isn't optimised to take full advantage of the vector arrangement it can be slower.

That's why AMD often has the lead when it comes to GPGPU applications and raw GFLOPs, but sometimes trails Nvidia for gaming performance; the predictable nature of GPGPU tasks means data can be optimised to best take advantage of AMD's SIMD approach, whereas gaming is less predictable, so performance is less reliable.

Other differences become evident as you zoom outwards. AMD combines four SIMDs (for a total of 64 stream processors) with a single scalar unit (for performing occasional quick non-vector operations – like a small nod towards Nvidia's approach), a hardware scheduler that manages the distribution of the instructions, four texture filtering units, 16KB of L1 cache and a few other bits to create a Compute Unit (CU).

The nearest Nvidia equivalent is the Streaming Multiprocessor, which combines 64 CUDA cores with four texture units, 64KB of L1 cache, and several other specialised components. However, you can see that a CU and SM aren't really on an even footing.



Next, AMD combines several CUs (nine in the RX480) and couples them with a geometry processor, rasteriser and four render back ends (ROPs) to make a Shader Engine (SE).

Meanwhile, Nvidia takes ten SMs (TPCs) and combines them with a Raster Engine to create a Graphics Processing Cluster (GPC).

The SE and GPC are the final main two blocks into which the two companies divide their GPUs. The result is that the RX480 has four SEs, 36 CUs, 144 SIMDs and 2,304 stream processors. Meanwhile, the GTX 1060 has two GPCs, 20 SMs and 1,280 CUDA cores. Simple.

VRAM

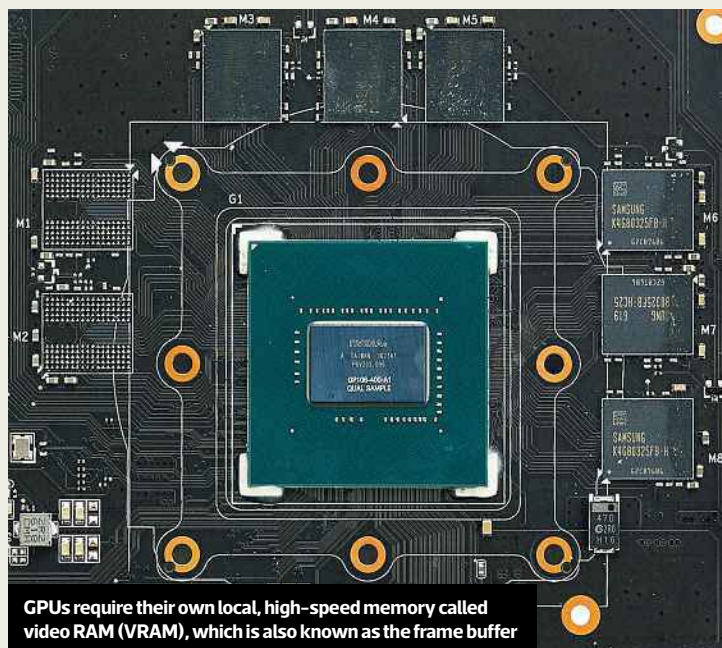
To keep these powerful processors fed with enough data, GPUs require their own local, high-speed memory called video RAM (VRAM). Also known as the frame buffer, this memory stores all the data – vertices, textures, shadow maps and so on.

Theoretically, with VRAM, it's a case of the more and faster, the better. However, that isn't always the case. The amount of memory used varies greatly from game to game. For instance, on p50 we tested several games to see how much VRAM they use and it varied from 1,736MB to 4,132MB just running at 1080p. As such, if you're wondering how much VRAM you need, there are a couple of factors to keep in mind.

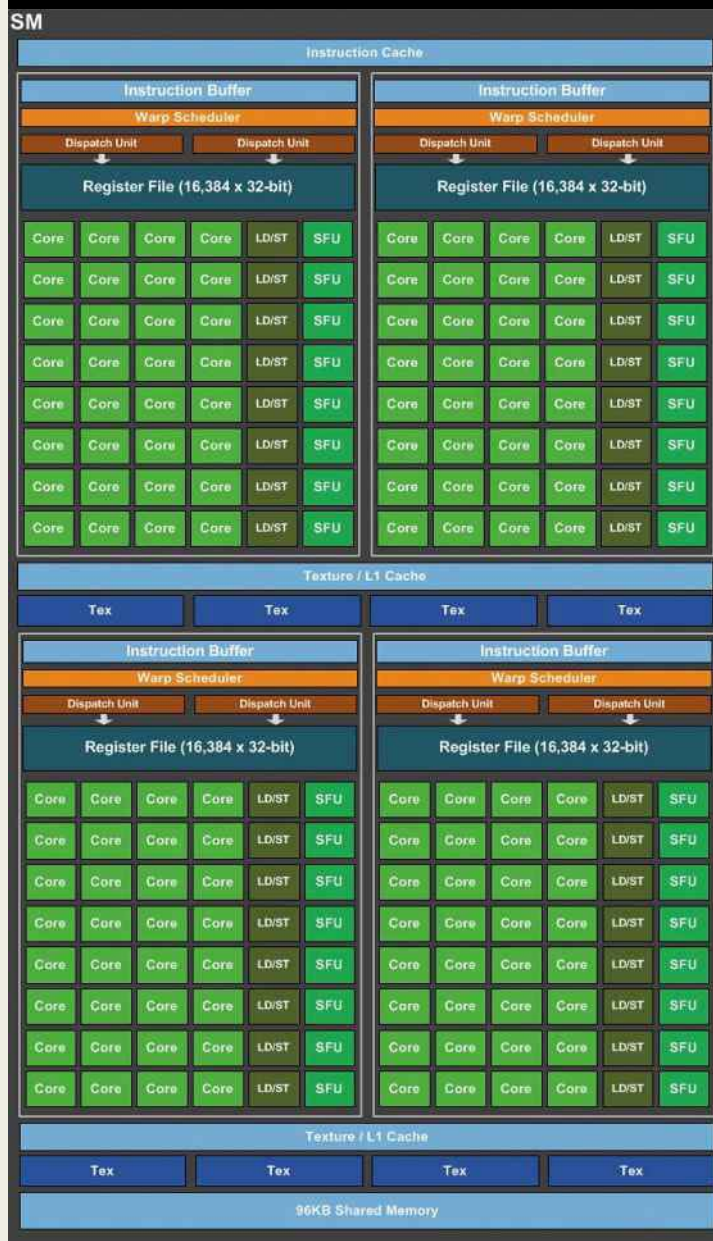
One is the resolution. The greater the number of pixels, the more data needs to be processed. Another potentially big VRAM hog is anti-aliasing (AA), although it depends which type you use as some of the most recent versions (FXAA, SMAA and MLAA) are very efficient. The third most obvious VRAM hog is high-resolution textures.

A reasonable rule of thumb is to consider whether you're after image quality or speed. If you have a relatively low-resolution monitor and your primary consideration is to never drop below 100fps, you'll get away with less VRAM on a faster overall card. If, however, you have a 4K screen and want games to look their best at 60fps, then the more VRAM the better.

Also, if you're running multiple GPUs, note that VRAM isn't added up. All the cards will constantly sync up their VRAM for data consistency, so you only ever get as much VRAM as you have on the smallest card.



NVIDIA STREAMING MULTIPROCESSOR



At the budget end of the market, you'll also encounter cards that are way too slow to take full advantage the amount of VRAM they're allocated. A quick browse through some online retailers reveals that you can buy the likes of the Nvidia GeForce GT 730 with a ridiculous 4GB of VRAM, for example, when the 1GB version will do fine at the game settings this GPU can realistically handle.

MEMORY INTERFACE

As well as the amount of memory, there's the memory bandwidth to consider. To calculate it, you simply multiply the memory clock speed by the memory bus-width. For the GeForce GTX 1060, this gets you 192GB/sec and the Radeon RX480 manages 224GB/sec.

Look out for cheap cards with narrow memory bus-widths – sometimes they'll be halved compared with the standard card, which can severely impact performance.

HARDWARE VIDEO DECODING / ENCODING

Both AMD and Nvidia's last several generations of graphics cards include a degree of hardware video decoding and encoding support, massively increasing speed and reducing power consumption compared to performing these tasks on a general CPU, or even the GPU's stream processors. Moreover, the encoding hardware allows for video to be recorded while you're playing games, meaning there's next to no performance impact – ideal for live streaming and recording.

Neither decoding nor encoding will work in all apps, as they require developers to specifically add support for these hardware encoders. For instance, VLC works for playback (decoding) while Open Broadcaster Software supports encoding. With their latest cards, both AMD and Nvidia have stepped up their offerings.

For playback, AMD's Unified Video Decoder (UVD) now offers HEVC decode a 4K at up to 60fps (4K60), including Main 10 profile support for 10-bit colour processing (for HDR video). VP9 decode is also supported, as is M-JPEG at up to 4K30. All of this is on top of all the previously accelerated codecs, such as H.264, MPEG2 and so on. Meanwhile, Nvidia's PureVideo offers 8K H.265/HEVC video decode as well as HEVC Main 12 for 12-bit colour depth decode and VP9 at 4K30.

As for encoding, AMD hasn't changed much on its latest GPUs. The RX400 series supports the company's Video Coding Engine level 3, so they can encode 8-bit HEVC at up to 4K60. Meanwhile, Nvidia supports HEVC Main 10 for 10-bit encoding, and its encoding performance for 4K H.265 and HEVC has also been doubled. Plus there's support for HEVC 8K, 4:4:4 chroma subsampling, lossless encoding and sample adaptive offset.

Nvidia currently has the overall edge for video playback and encoding, although the number of users who will take advantage of all these features is likely very small.

GPGPU

Of course, GPUs can also be used for other highly parallel workloads aside from games, often known as general purpose GPU (GPGPU), or compute, work. In essence, with non-graphical calculations, the GPU just turns over its stream processors to whatever task is asked of them while the rest of the GPU-specific hardware is ignored.

However, there's also an increasing use of non-graphical calculations such as physics and audio in games, which require the GPU to switch states from a graphical workflow to a general workflow, which isn't a trivial achievement if you want to avoid affecting overall performance.

That's where 'asynchronous compute' comes in, with AMD and Nvidia implementing their own methods to reduce the impact of switching states. AMD uses a hardware asynchronous compute engine to manage the rapid switch from one compute state to the other. Nvidia doesn't have this feature, but uses several pre-emption techniques to keep its load under control.

CONCLUSION

Of course, there's only so far you can simplify the explanation of complicated processors that are made up of billions of transistors and deal with incredibly graphically sophisticated games. The deeper you dig, the more there is to learn. Nonetheless, when you next come to read a graphics card review, or compare specs between GPUs, this knowledge will help to give you a better understanding. **GPG**



THE ART OF WAR

Video games have long been fascinated with war, but the way they depict conflict is changing. Rick Lane investigates the shift to a realistic, human representation

War has been a staple topic of gaming for almost as long as gaming has existed. Whether it's blasting lines of aliens in *Space Invaders*, shooting Nazis in *Call of Duty* or battling a Dark Lord in *Dragon Age*, gaming has represented large-scale, armed conflict in just about every way imaginable.

Yet for all the time and money developers spend on depicting war, until recently, games gave little

thought to *exploring* war. Whether it's a spectacular FPS or a grand strategy game, most games that depict war are only concerned with the machine itself—the soldiers, the technology and the spectacle. Mainstream developers such as Infinity Ward and DICE spend large sums of money on rendering gun barrels in exquisite detail, or animating pixel-perfect explosions, while thousands of man hours are consumed with calculating bullet collisions with exacting precision, and building a

convincing soundscape of gunfire, artillery and screams.

Games excel at representing war, but they rarely examine war in a wider context; the effect it has on people, whether they're partaking in the war, caught up in it or simply live nearby. But this situation is now changing. In the past few years, a handful of games have started looking beyond the awesome and grisly spectacle, adopting a more nuanced perspective. There are games that criticise how



Games such as Call of Duty 4 do an incredible job of recreating war's spectacle, but don't go much deeper

shooters represent war, games that ask what it's like to be a civilian in a city under siege, and games that try to depict war in its everyday totality.

But it isn't simply the way these games depict war that makes them fascinating. It's also how it makes them better games. Even though they all examine war from different angles, their roads ultimately lead back into the game's overall design, resulting in games that aren't just more thoughtful and empathetic about war, but also unique and compelling to play.

The soldiers' story

One of the most significant games to break the mould is Spec Ops: The Line. Released in 2012, on the surface, Spec Ops appears to be a standard linear covershooter, revolving around a team of highly trained soldiers attempting to extract a rogue general from Dubai, after it was destroyed in a sandstorm. But Spec Ops is really a story about the protagonist, marine Scott Walker, and how his mental state unravels as he pursues his goal with destructive single-mindedness.

This unique perspective is largely down to Walt Williams, lead writer on the project. Williams explains that the game's unusual slant on an action-game storyline came about as a consequence of trying to portray the Spec Ops team as normal soldiers rather than gung-ho action heroes. 'We wanted them to feel like real soldiers in a real situation, and that's when we began to see that disconnect,' Williams says. 'If we were just writing them as video game characters, then



everything they did would be totally fine, but as soon as we tried to make them react realistically to it, everything they did became very illogical.'

In a standard shooter, the main character will gun down hundreds of enemies without batting an eye, whereas in real life, even in combat situations, only a fraction of the soldiers involved will actually kill someone. To participate in the kind of slaughter that Walker's team undertakes in Spec Ops will put a lot of mental stress on a person.

Spec Ops has frequently been praised by critics for its portrayal of soldiers with post-traumatic stress disorder, on account of how the soldiers increasingly struggle to hold their grip on reality as the situation worsens. In the second half of the game, Walker suffers increasingly from aural and visual hallucinations, mistaking his friends for enemy soldiers and vice versa. However, Williams is keen to emphasise that the team made no attempt to depict the experience of PTSD.

Spec Ops is set in a Dubai half-buried by sand. Lead writer Walt Williams refers to it as a 'hyper-realised' world

'I was hesitant to try to recreate a simulation of PTSD, because I felt it would be disrespectful to people who have PTSD. Obviously, Spec Ops is a very hyper-realised world – even the level of sand is an extreme.' Williams also points out that 'right now he's just in shock because he's still in the trauma, which hasn't ended, so it can't be PTSD.'

Indeed, although Spec Ops: The Line depicts some horrific atrocities that are committed in war, it isn't a commentary on the nature of war itself. Rather, it's a commentary on how shooters such as Call of Duty and Battlefield normalise those horrors and turn them into entertainment. 'This is what you don't want to look at, this is what you choose to ignore, every time you play a shooter,' Williams says.

Spec Ops also depicts the destructive, self-perpetuating cycle of war. In the game's most infamous scene, Walker uses a mortar to bombard an enemy depot with white phosphorous grenades. In the process, he inadvertently incinerates a shelter

Spec Ops' 'White Phosphorous' scene radically altered our perception of what war games can do



filled with civilians, whom the opposing force were keeping safe from the fighting. When he realises what he's done, Walker's doesn't accept or deny what he's done. Instead, his immediate response is simply: 'We need to keep moving.'

'With Spec Ops, it was more about trying to figure out where Walker's guilt really lay, and how that would manifest itself,' Williams explains. 'These two specific moments are really coming back at him. One is that he's done something wrong for which he's to blame, which is the killing of the civilians, and the second is that he just needs to stop – by continuing to go forward he's only making things worse.'

Wars are often protracted by the sunk-cost fallacy, the belief that continuing to invest your time and effort into a failing project will ultimately reap a reward, when in reality, you're just worsening an already-bad situation. But in most war games, this fallacy is represented as a truth. Despite the torment, the main character endures, and the inordinate amount of destruction for which they're responsible, they ultimately emerge victorious, and everything returns to normal. Spec Ops shows the more likely outcome of such a mindset – that a war can only end when both sides agree to stop fighting.

The regular people's story

Spec Ops demonstrated that games don't need to glorify war in order to create an interesting and entertaining experience, but it's mainly the writing and storytelling that makes Spec Ops a unique and interesting game. In terms of plays, it remains a fairly derivative shooter.

One game that adopts a more systemic approach in its representation of war is *This War of Mine*. Developed by the Polish team 11 bit Studios, *This War of Mine* puts players in charge of a group of civilians attempting to survive a city siege.

During the day, you stay indoors and attempt to improve the conditions of your safehouse. You explore new floors, construct beds and other equipment, and see to the needs of your civilians. At night, one of the survivors braves the sniper-watched streets to go on a scavenging run.



Raiding shops and buildings for supplies can lead to difficult moral quandaries

'It was my brother's idea – Grzegorz Miechowski – who is a CEO at our company,' says Pawel Miechowski, senior writer at 11 bit Studios. 'He was reading articles about how people survive war, what happens with them, what they remember and, importantly, their most significant memories. At the time, we had a prototype game about surviving and he said we should have made a game about surviving war as regular people.'

Tackling civilians in wartime is a tricky challenge. For starters, you lose the great gaming crutch that is combat, and have to find other means to keep the player interested. In addition, this subject needs to be treated with delicacy and nuance. To that end, 11 bit Studios researched city sieges throughout the 20th century, including the Yugoslavian War, the siege of Aleppo, the Bosnian war and the Warsaw uprising of 1944, an event that held particular significance for the Polish team.

'It's easy to find stories from war in Poland from our grandmothers and

grandfathers, as they survived German and Russian invasion during WW II,' says Miechowski.

The developers took inspiration from all these conflicts, combining them to set the game in a fictional, unnamed conflict. 'We didn't want to base the game on a one specific conflict because we wanted to avoid any political connotations, and we wanted to provide a universal experience for everyone around the globe.'

Aside from its subject matter, *This War of Mine* also eschews a Spec Ops-style storyline in favour of a more freeform, emergent style of play. It shares systemic motifs with other survival games, such as exploration, scavenging resources and crafting useful items. However, the ingenuity behind *This War of Mine* is the way it uses these systems to raise difficult moral quandaries, and highlights that war doesn't just bring the worst out of soldiers, but other people too.

When your survivors go out on a supply run, for example, they could raid abandoned buildings, but risk them being empty. Alternatively, they could break into somebody's home, and help themselves to what they need, while the residents helplessly implore you to stop. Again, however, such actions aren't without potential consequences. Your survivors aren't automatons, they're human beings driven by emotion as much as their more basic needs. Stealing from other survivors runs the risk of triggering a spike of depression, which can render that particular survivor useless for a long time.

In this way, *This War of Mine* encourages you to make your own decisions, and deal with how they affect your survivors and other civilians. 'A scripted storyline would

Your survivors aren't automatons; they're human beings driven by emotion as much as their more basic needs

make it a linear experience in which you're more of a spectator than a narrator,' says Miechowski. 'To make it a personal experience in which you invest yourself, ignite emotions and make morally grey choices, we had to make an environment in which you tell stories rather than follow a pre-written one.'

As with *Spec Ops*, *This War of Mine*'s attempt to explore war from an unconventional angle, rather than simply using it as a springboard for an action game, feeds back into the quality of the overall experience. It adds an extra edge to the survival systems, forcing you to judge the value of your own survivors' lives against those of other survivors.

The fantasy warfare story

Both *Spec Ops* and *This War of Mine* present a very specific situation, through which they explore a particular aspect of war. But is it possible for a game to examine the subject in a broader fashion, while retaining that same level of nuance? Until last year, the answer was no. Then along came CD Projekt's *The Witcher 3*, a game that offers a truly remarkable depiction of large-scale conflict.

What makes it all the more remarkable is that *The Witcher 3* is a fantasy game. It sees Geralt of Rivia searching the land of Velen, which has been torn apart by war, for his missing adoptive daughter. But unlike most games that revel in the thrill of battle, *The Witcher 3* shows us war as a way of life, rather than a collection of cacophonous moments. The fighting between the Northern Kingdoms and the Empire of Nilfgaard has ground to a bloody halt, with both sides licking their wounds and eyeing each other up over the vast expanse of Velen's No Man's Land.



As Geralt traverses the swampy, wild terrain of Velen, the land is scarred with reminders of the war. There are vast areas where the countryside has been churned to mud by battle, the ruptured earth scattered with decomposing bodies and smouldering pyres, feasted upon by crows and monstrous necrophages such as ghouls and rotfiends. Ragged flags and banners flutter pointlessly in the breeze. Some roads are lined with gibbets from which dangle the corpses of traitors and deserters, while armed patrols from both armies wander the dirt lanes that weave between the swamplands. To the south is a huge army camp, its timber walls and towers spiking into the sky, its gleaming white tents visible all the way to the horizon.

It's an incredible portrayal of the destructive power of war, and all the more haunting for the fact that we come to it *after* the destruction has taken place. But although Velen is a battered landscape, it's far from a dead one. Amid the blood and chaos are small peasant villages where the inhabitants try their hardest to get on with their lives. Children play gleefully in the streets, while women wash clothes in wooden tubs, and the men toil away in the sun-dappled fields. In these little havens of peace, you almost wouldn't believe there was a war going on at all. But other villages

With war raging all around them, *The Witcher 3*'s peasants do their best to get on with life

are patrolled by soldiers, or raided by thieves in the night. Several villages have been destroyed, the peasant huts shattered, thatch roofs billowing smoke and there's a trailing queue of refugees at a river crossing that leads to the Northern city of Novigrad.

Playing as Geralt, a travelling monster hunter for hire, we get a perspective of war from all angles. We hear the peasants complain about the soldiers, the soldiers complain about their commanders and the commanders complain about the war's slow, costly progress. We hear the justifications for the fighting from each camp, and witness heroism and atrocities on both sides.

The Witcher 3 doesn't just show you the war, it immerses you in it, debating and deliberating with all comers. It brings to the fore the emotions of war, the boredom, the frustration, the desperation, the determination to carry on in the hope that tomorrow will be better. It allows the player to make a small contribution here and there, liberating an abandoned settlement from bandits or monsters, or hunting down a dangerous monster on behalf of one of the armies. Mostly, though, it highlights that you're just one, small individual caught in a huge, uncompromising machine.

Where do war games go from here? For many, it will be business as usual – big guns and bigger explosions.

But there are glimmers of a better war. This year's *Battlefield* sets its sights on World War I, a conflict generally avoided by games due to its culturally sensitive nature.

There will be an onus on the developers to show not just the spectacle of the war, but the horror of it too. It could just be another bombastic shell of a game, but it could also represent another step forward in how games explore their favourite subject. **GPG**





GARETH HALFACREE'S

Hobby tech

The latest tips, tricks and news in the world of computer hobbyism, from Raspberry Pi, Arduino and Android to retro computing

REVIEW

Sugru Rebel Tech Kit

Sugru is, it has to be said, a remarkable product. Developed by a team of scientists working under Jane Ní Dhulchaoitigh in the materials department of Queen Mary, University of London, Sugru (derived from the Irish word *súgradh*, for play, and more technically known as Formerol) is cheap, easy to use, safe and has loads of uses. The only problem is easily communicating all those many uses.

For those of you who have never seen Sugru, the new Rebel Tech Kit is designed to act as an introduction. Now sold under the tagline 'mouldable glue,' giving at least a hint as to its purpose, Sugru is a soft, pliable putty that hardens into silicone rubber overnight. It has found uses in all sorts of areas, from revamping kitchen appliances to insulating electronics and even providing new grips on hand-held objects, readily sticking surfaces together.

That's a hard description to fit on the packaging so that buyers can absorb it at a glance, however, and the previous package sizes – where 12 individually packaged portions of Sugru was the smallest allowance

– meant people were less willing to take the plunge and experiment.

The Rebel Tech Kit aims to fix this problem, offering a newcomer's introduction to the joys of Sugru. The front of the box hinges out to reveal a detailed summary of the contents: sachets of white, black, red and grey Sugru, a small metal tin to store the sachets and a

booklet detailing 14 projects culled from the community. There's also a small guitar pick, which makes it easier to add patterns or form a sharp edge.

It's the booklet that really helps to sell the kit. While subscribers to the Sugru newsletter find their inboxes filled with neat hacks and fixes once a month, newcomers have no such benefit. Printed in full colour on glossy paper, the booklet's projects are all basic enough for Sugru novices. Starting with repairing frayed electrical cables, one of the most common uses for Sugru, the booklet runs through various ideas, including making Sugru spikes for the base of your freestanding speakers to improve audio quality, and adding multicoloured bumpers to an old digital camera to make it suitable for kids' use.

There are no groundbreaking ideas in the booklet, but it offers enough to debunk the 'mouldable glue' tagline; of the 14 projects included, only four involve using Sugru to glue two objects together. The remainder makes use of its properties once it's cured – the fact that it's mouldable and pliable when fresh, but then turns into a hard rubber 24 hours later. It's this aspect that makes it suitable for adding hooks to surfaces, so you can hang backup drives to the rear of a monitor or



The Sugru Rebel Tech kit is designed as an introduction to the world of 'mouldable glue'

You can revamp kitchen appliances, insulate electronics and even make new grips for hand-held objects

headphones on the side of a hi-fi, and for customising the grips and buttons of cameras and gamepads.

I've been using Sugru for a while now, and the sachets included in the Rebel Tech Kit are no different. Simply wash your hands, cut open the packet and then knead the Sugru between your fingers until it's soft. Apply it to clean surfaces, shape and smooth it with a little soapy water and then leave it alone for a day to let it cure. I used one sachet to repair the micro-USB cable I use to charge my phone, which was beginning to fray thanks to inadequate strain-relief moulding, and I completed this job in just a couple of minutes. Also, one of my slightly more involved projects from a few years ago involved using bright orange Sugru to customise the scales of a Leatherman multi-tool, and to improve its grip during use.

There are a few catches, of course. Sugru is a bit of a pain to clean off your hands, thanks to its sticky nature, and the stronger colours can stain a little while in their fresh, pre-cured state. It also has an unpleasant, almost disinfectant-like smell, although this smell disappears early on in the curing process and is undetectable once finished.

The tin is also of questionable value. It's small, cute and offers a handy way to carry around a few sachets of Sugru, but if you want



The bundled Sugru sachets are best kept in the fridge, though the tin at least makes for easy carrying

The projects in the bundled booklet are mostly basic, but serve as a good starting point

your Sugru to last long, it should be kept in the fridge rather than your pocket or backpack. As a gift for someone who has never tried Sugru before, or as a neat introduction to the material yourself, though, the kit as a whole is easy to recommend.

If, like myself, you end up a Sugru convert, various colours are available in packs of eight for £12.99 inc VAT and packs of three for £6.99 inc VAT, while the alternative Home Hacks Made Easy Starter Kit includes five sachets and a smaller projects book for £10 inc VAT. There's even a kit that includes three



black sachets and a set of neodymium magnets, which costs £12 inc VAT. The Sugru Rebel Tech Kit is scheduled to launch on <https://sugru.com> in early October, priced at £10 inc VAT.



A custom Leatherman multitool, one of my first Sugru projects.



Sugru feels like soft Blu-Tack, but hardens within 24 hours to a firm silicone rubber

REVIEW

Arduino IDE 1.6.11

Even the most ardent Arduino fans would be hard-pushed to call the Arduino IDE 'exciting'. Useful, yes; easy to use, certainly. It's rare that a release is different enough from its predecessors to justify a two-page review though.

The previous most exciting event in the world of the Arduino IDE was the integration of the Boards Manager, allowing you to add new hardware definitions quickly and easily in order to support new and exciting microcontrollers.

For users of AVR-based Arduinos (any device with an ATmega or ATtiny chip), from the popular Arduino Uno to the esoteric London Hackspace Nanod, that lack of excitement changed with the launch of Arduino IDE 1.6.10. In its release announcement, Arduino.cc boasted of the addition of link-time optimisation (LTO) to the compiler toolchain for AVR boards, promising that sketches would run faster and take up less flash storage space. Naturally, I felt the need to verify those claims.

First, though, there's a complication. The Arduino IDE itself is currently at version 1.6.11 but each bundled toolchain, to which the IDE refers as Cores or Board Definitions, has its own versioning system.

There's the AVR Core, the SAMD Core, the x86 Core, the ESP8266 Core and more, and none of the version numbers track the IDEs with which they're released. This review covers version 1.6.11 of the Arduino IDE, which is the latest stable release at the time of writing, but the AVR Core 1.6.13. If you're playing along at home, use the Boards Manager tool in the IDE to make sure you're also running AVR Core 1.6.13 or higher, or you'll see very different results.

With that in mind, let's get onto the testing. Armed with a Genuino Uno, the non-US rebrand of the ATmega328-based Arduino Uno, I used a series of benchmarks to measure the change between the AVR Core 1.6.9 bundled with the original Arduino IDE 1.6.9 release and the latest AVR Core 1.6.13.

Sketch size is vital for AVR-based Arduinos. An ATmega168-based Arduino Nano has just 14KB of flash storage accessible to the user, and even the relatively capacious ATmega328-based Uno has to make do with 31.5KB once the bootloader is installed. The flash portion of the chip is where the compiled binary produced by your sketch is



Now these performance gains have been achieved, perhaps the user interface could be the next step for the Arduino team?

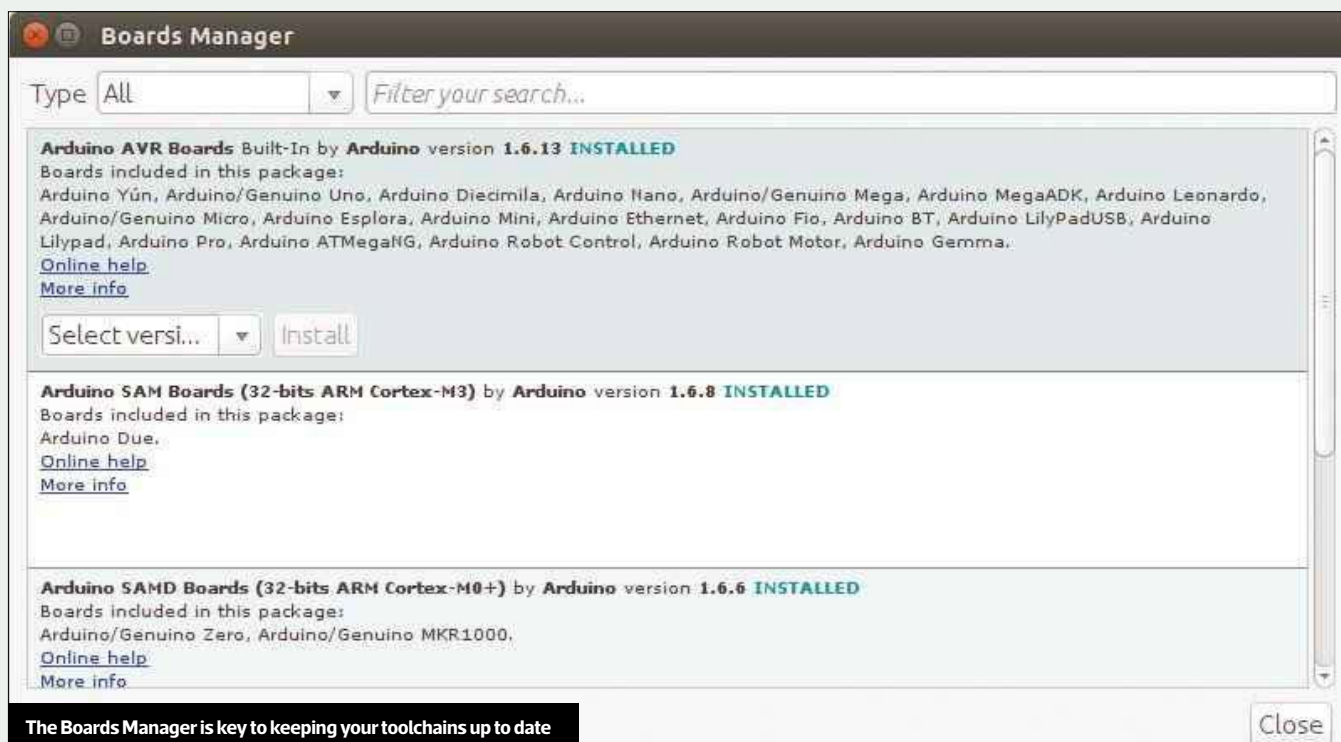
stored. If the binary is too big, the sketch simply won't upload.

To get best-case and real-world scenarios, I compiled several sketches using both the 1.6.9 and 1.6.13 AVR Cores: the example BareMinimum.ino and Blink.ino sketches, and the Dhrystone and Whetstone benchmarks. Sure enough, each was smaller with the new Core: while the empty BareMinimum sketch just dropped from 450 bytes to 444 bytes, the larger sketches showed considerable improvement, with Blink dropping from 1,030 bytes to 928 bytes, Dhrystone from 6,150 bytes to 5,350 bytes and Whetstone from 6,128 bytes to 4,918 bytes. So far, so good.

Arduino.cc promised performance gains too, so the next job was to load the Dhrystone (integer) and Whetstone (floating-point)

benchmarks into the Uno. Here's where the new Core becomes impressive: the Dhrystone result jumped from 6.25 million instructions per second (MIPS) to 10.15 MIPS, while the floating-point Whetstone result went from 1.17 million Whetstone instructions per second (MWIPS) to 6.23 MWIPS. That's a six-fold increase in floating-point performance, enough to beat the 32-bit ARM Cortex-M0+ Genuino Zero, which costs twice the price, and this all comes from simple, invisible compiler optimisations – there's no change to the sketch code at all.

For the final test, I looked to a more real-world AVR usage scenario: input-output (IO) performance. Here, my IOBench benchmark was used to take three measurements. The first two measurements are soft read and write, which simply time how long it takes to

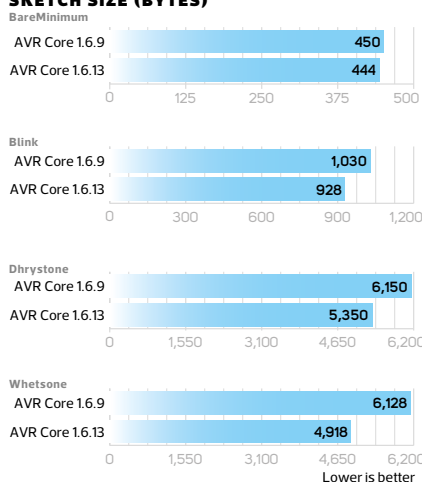


run a few thousand `digitalRead()` and `digitalWrite()` instructions. The third measurement is hard write, which toggles a pin connected to an external frequency counter – it can then get a true reading of how quickly a digital pin can be physically toggled on and off by the microcontroller.

The soft, synthetic benchmarks showed the type of improvement you would expect after seeing the Dhrystone and Whetstone results: read performance went from 159.03KHz under the older Core to 260.71KHz, and write performance from 140.74KHz to 178.69KHz. The real-world pin-toggle test, though, revealed a much more sedate improvement: the IOBench sketch compiled under AVR Core 1.6.9 ran at 95.66KHz, while switching to AVR Core 1.6.13 saw a mild increase to 108KHz.

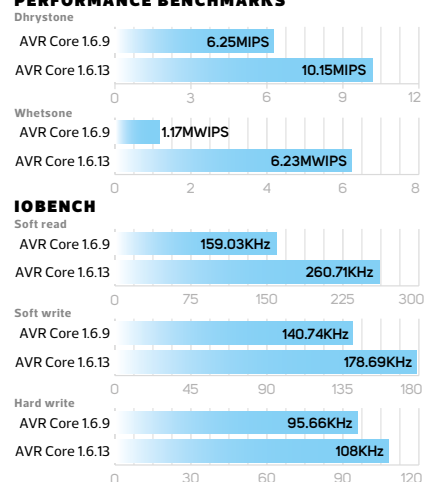
Arduino.cc never promised the world though: the team said the new AVR core

ARDUINO IDE BENCHMARKS SKETCH SIZE (BYTES)



would improve performance and reduce binary sizes, and it achieves this goal. If you're an AVR user, that's a good enough

PERFORMANCE BENCHMARKS



reason for you to download the latest update from www.arduino.cc and reap the benefits yourself.

NEWS IN BRIEF

Intel announces Joule kits

Intel is continuing its push into the high-end maker market with the launch of Joule, a computer-on-module (CoM) system based around the quad-core 1.5GHz Atom T5500 or 1.7GHz T5700 Atom processors. The modules include 3GB or 4GB of LPDDR4 memory and 8GB or 16GB of eMMC flash memory, onto which a customised Linux distribution is pre-loaded.

Both modules also include Intel HD Graphics, 802.11ac Wi-Fi, and Bluetooth 4.1 radio modules. UK pricing has yet to be confirmed, but



the top-end Joule 570x kit, which includes a breakout board for the module, costs \$369 US (around £284 ex VAT).

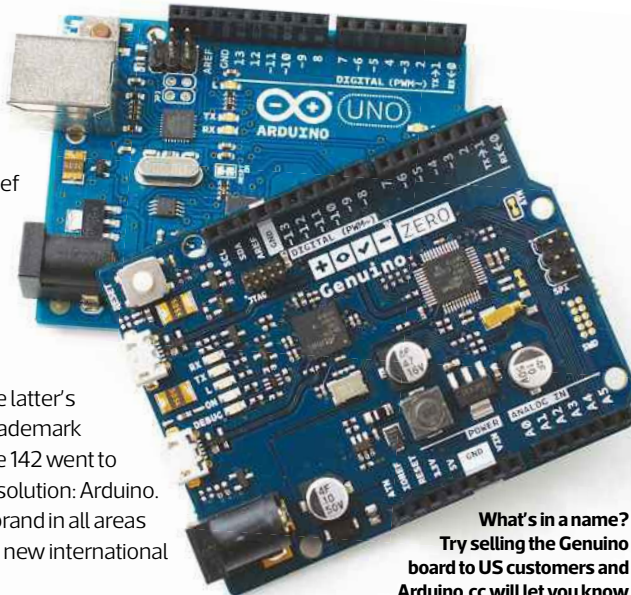
ANALYSIS

Arduino suffers Genuino backlash

Regular readers may recall the Arduino.cc vs Arduino.org legal wranglings from Issue 142. For anyone else, here's a brief recap: the original founders of the Arduino project, who run the Arduino.cc domain, have been battling a spin-off created by a former co-founder in charge of the Arduino.org domain, and the latter's ownership of the Arduino trademark outside the USA. Since Issue 142 went to press, there was a partial resolution: Arduino.cc abandoned the Arduino brand in all areas except the USA, launching a new international brand called Genuino.

Sadly, all has not been going smoothly. The Genuino name has failed to get the traction enjoyed by Arduino, and has only confused matters: an Arduino Zero and a Genuino Zero are identical bar the silk-screen and packaging, but the far more similarly named Arduino Zero Pro is a different product from a different company.

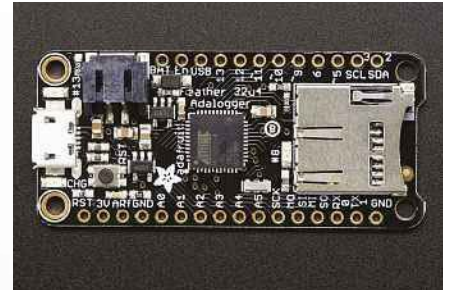
Arduino.cc is compounding the issue with ill-thought-out restrictions on its wholesale customers. As the holder of the lucrative Arduino trademark in the USA, the company continues to sell Arduino-branded boards there; only boards sold outside the USA receive the Genuino branding. However, while Arduino.cc's own web store can control which



What's in a name?
Try selling the Genuino board to US customers and Arduino.cc will let you know

product goes where, it's proving impossible to do the same with wholesale customers.

In a blog post entitled 'Why we won't be selling Genuino or Arduino any more,' Jon Williamson of Pimoroni lays out the trouble: if you're an international customer, you have to guarantee to Arduino.cc that it's physically impossible for a US resident to order a Genuino-branded board. If, like Pimoroni, your shop is open to US customers, you need to stock both Arduino-branded and Genuino-branded boards – doubling the number of stock keeping units (SKUs) you need to buy and track, while ensuring that each one is only accessible to its respective nation.



Sellers are increasingly pointing customers to third-party compatibles rather than Arduino originals, such as this Adafruit Feather board

'You want us to stock twice as many products, half through an entirely different supply channel, which are identical bar the writing on them, and then enforce that our customers pick the correct version,' an incredulous Williamson wrote about his discussions with Arduino.cc, which took a full seven months to even begin. 'Yeah, good luck with that.'

While Arduino.cc holds the Arduino trademark exclusively in the USA, and thus could land in legal hot water if it sells Arduino-branded goods internationally, it holds the Genuino trademark internationally. In other words, there's no legal risk in a Genuino-branded board tipping up in the USA.

'It's a real shame that Arduino LLC [Arduino.cc] seem to have lost any of the maker-vibe it had,' he writes. 'They seem more preoccupied in playing at pretending to be one of the big boys with lawyers working double-time and focussing on "brand identity" to the detriment of anything else.'

Initially, Pimoroni refused to agree to Arduino.cc's terms, instead allowing its existing stock of Genuino boards to run out and pointing buyers to compatible alternatives, including the Adafruit Feather and SparkFun RedBoard. Since the dispute went public, Arduino co-founder Massimo Banzi has reached out to the company and discussions are ongoing.

'Paul and I have spoken with Massimo Banzi from Arduino LLC about the issues,' Pimoroni wrote in an update. 'We're confident that changes will be made to fix the situation for resellers.' See <http://blog.pimoroni.com> for more information. **GPC**

NEWS IN BRIEF

WirelessThings shuts doors

WirelessThings, the Nottingham-based Internet of Things (IoT) company formerly known as Ciseco, has officially closed as of 8 September, 2016. Best known for its Raspberry Pi- and Arduino-compatible radio products and smart sensor modules, WirelessThings' parent company Agile 365 (which acquired the company in 2015) stated that the subsidiary was considered to be no longer a core part of its plans. All staff members are understood to have been laid off. The Ciseco Pi-Lite and Raspberry Pi Wireless Inventors Kit were both positively reviewed in Issue 121.



Gareth Halfacree is the news reporter at www.bit-tech.net, and a keen computer hobbyist who likes to tinker with technology. [@ghalfacree](https://twitter.com/ghalfacree)

CUSTOM PC

REALBENCH 2015

in association with 

Give your PC a workout with our new benchmark suite, and see how your rig compares to other readers' machines

Gimp

We use Gimp to open and edit large images. Unlike our previous Gimp test, this one uses more than one CPU core, although it's still more sensitive to clock speed increases than more CPU cores.

Handbrake H.264 video encoding

Our heavily multi-threaded Handbrake H.264 video encoding test takes full

SHOUT OUTS!

There are no new entries in the top 20, but we've seen some movement in the chart, with dax upgrading to an Asus Rampage V Edition 10, increasing the system score to 194,595 and jumping from number 20 to 19. Meanwhile, Nik has improved his system score of 193,102 to 196,095, while holding the number 18 spot.

advantage of many CPU cores, pushing them to 100 per cent load.

LuxMark OpenCL

This GPU compute test is the only synthetic part of our suite, although the renderer is based on the real LuxRender physically based rendering software. As 3D rendering is a specific workload that not everyone will use, and because OpenCL support isn't standard in most software, this section is given just a quarter of the weighting of the other tests in the final score.

Heavy multi-tasking

Our new multi-tasking test plays a full-screen 1080p video, while running a Handbrake H.264 video encode.

Scores

RealBench 2015 breaks down the scores for each test, then gives you a total system score and a percentage reference score.

BENCHMARK YOUR PC

Download the benchmarks from www.asus.com/campaign/Realbench and, before you run them, disable any power-saving technologies in your BIOS that change your CPU clock speed, or the leaderboard won't record your overclock frequency properly. To post a score on the leaderboard, go to Save Upload File in the RealBench 2015 app's Results menu, and save your results in an RBR file. You need to select Offline Uploads on the leaderboard site, sign up for an Asus account and upload your file.

On an Intel system, the 100 per cent reference score comes from a stock-speed Core i7-4790K, with 16GB of Corsair 2400MHz DDR3 memory, a 240GB OCZ 150 SSD, an Asus Maximus Gene VII motherboard and an Nvidia GeForce GTX 780 3GB graphics card.

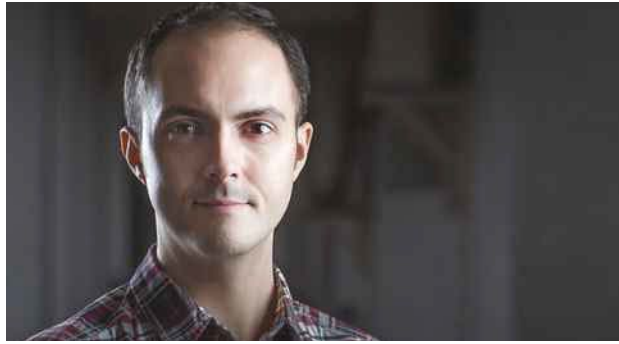
On an AMD system, the 100 per cent reference score comes from a stock-speed A10-7850K APU, with 8GB of Corsair 2,133MHz DDR3 memory, a 256GB Plextor M5 Pro SSD and an Asus A88X-Pro motherboard, using the APU's integrated graphics. **GPG**

CHROME WARNING

At the moment, Google's Chrome browser flags up the RealBench 2015 download as potentially harmful, and we're aware of this issue. The file is perfectly safe, however – please ignore this warning.

CUSTOM PC REALBENCH 2015 LEADERBOARD

RANK	SYSTEM SCORE	REFERENCE	USERNAME	MOTHERBOARD	CPU	CPU CLOCK	MEMORY	PRIMARY GPU
1	275,683	240.9%	8pack	Asus Rampage V Extreme	Intel Core i7-5960X	5.5GHz	16GB Kingston 3000MHz	Nvidia GeForce GTX Titan X
2	233,375	203.9%	ian.parry3	Asus Rampage V Extreme	Intel Core i7-5960X	4.6GHz	32GB G.Skill 3200MHz	Nvidia GeForce GTX Titan X
3	231,781	202.5%	CustomPC	Asus Rampage V Extreme	Intel Core i7-5960X	Not reported	32GB Kingston 2666MHz	Nvidia GeForce GTX Titan X
4	229,929	200.9%	mikey	Asus Rampage V Extreme	Intel Core i7-5960X	4.44GHz	16GB Corsair 2709MHz	Nvidia GeForce GTX 980
5	228,314	199.5%	smudgesmif	EVGA X99 Micro 2	Intel Core i7-6950X	Not reported	16GB Corsair 3200MHz	Nvidia Titan X (Pascal)
6	221,477	193.5%	Chris_Waddle	Asus X99-Deluxe	Intel Core i7-5960X	4.62GHz	16GB Corsair 3000MHz	Nvidia GeForce GTX Titan X
7	219,938	192.2%	roosauc	Asus Sabertooth X99	Intel Core i7-5960X	4.69GHz	64GB Corsair 2446GHz	Nvidia Titan X (Pascal)
8	219,415	191.7%	Luke@DinoPC	Asus Rampage V Extreme	Intel Core i7-5960X	4.6GHz	16GB Corsair 3276MHz	Nvidia GeForce GTX Titan X
9	216,006	188.7%	terrystone1	Asus Rampage V Extreme	Intel Core i7-5960X	4.61GHz	16GB Corsair 2992MHz	Nvidia GeForce GTX 980 Ti
10	215,694	188.5%	dubail	Asus X99-Pro/USB 3.1	Intel Core i7-5960X	4.7GHz	32GB Corsair 2800MHz	Nvidia GeForce GTX 980 Ti
11	212,062	185.3%	TEL	Asus Rampage V Extreme	Intel Core i7-5960X	4.62GHz	16GB Corsair 2750MHz	Nvidia GeForce GTX 980 Ti
12	211,331	184.6%	Mentholl	Asus Rampage V Extreme	Intel Core i7-5960X	Not reported	32GB G.Skill 3200MHz	Nvidia GeForce GTX 980 Ti
13	208,975	182.6%	Angel	Asus X99 Deluxe	Intel Core i7-5960X	Not reported	128GB G.Skill 2448MHz	Nvidia GeForce GTX 980
14	206,723	180.6%	stuart	Asus Rampage V Extreme	Intel Core i7-5960X	4.41GHz	16GB Corsair 3000MHz	Nvidia GeForce GTX 780 Ti
15	203,784	178.1%	simonedwards2003	Asus X99 Deluxe II	Intel Core i7-6950X	Not reported	64GB Corsair 2666MHz	Nvidia GeForce GTX 980 Ti
16	198,971	173.9%		Asus Rampage V Extreme	Intel Core i7-5960X	4.4GHz	64GB Corsair 2400MHz	Nvidia GeForce GTX 980 Ti
17	197,964	173%	Carbonleg	Asus X99-E WS	Intel Core i7-5960X	Not reported	32GB Corsair 2400MHz	AMD Radeon R9 200 Series
18	196,095	173%	Nik	Asus Rampage V Extreme	Intel Core i7-5960X	4.2GHz	64GB Corsair 2666MHz	Nvidia GeForce GTX 1080
19	194,595	170%	dax	Asus Rampage V Edition 10	Intel Core i7-5960X	Not reported	32GB Corsair 2133MHz	Nvidia GeForce GTX 980
20	189,230	165.3%	shadowsrayne	Asus Rampage V Extreme	Intel Core i7-5960X	4.2GHz	32GB Corsair 2133MHz	Nvidia GeForce GTX 980



ANTONY LEATHER'S

Customised PC

Case mods, tools, techniques, water-cooling gear and everything to do with PC modding

Will M.2 revolutionise modding and case design?

Cast your mind back to the early days of usable SSDs and you might remember just how this awesome technology stomped all over the performance of mechanical hard disks. These early SSDs only had small capacities of 64GB and 128GB, if you were lucky, but some of us, including myself, willingly tolerated pitiful amounts of OS drive space just for that speed boost. Of course, SSDs have moved on since then, and decent 512GB SSDs can now be bought for just over £100, and the next big step is moving away from 2.5in SATA SSDs to M.2 drives.

M.2 doesn't just support smaller SATA drives, but can also support PCI-E drives, using four PCI-E 3 lanes, depending on your motherboard and your drive. The extra speed on offer is many times that of SATA 6Gbps SSDs,



Who needs drive bays when you can get 1TB of super-fast storage on a small PCB?

Removing the drive bays gives you much more room in a small form factor system

and while the difference may not be as revolutionary as first moving from a hard disk to an SSD, there are still some noticeable improvements, with the potential to move data at around 4,000MB/sec.

I'm currently in the process of building a new mini-ITX system and, as part of the modding process, I've removed all the available storage bays to make way for water-cooling components. This idea didn't faze me, though, as the motherboard has an M.2 connector, and while I'd need a 1TB SSD to comfortably house all my data, these drives now exist. Earlier this month, I spotted one of Samsung's new 1TB Polaris-based M.2 SSDs (no relation to AMD's Polaris GPUs) for sale at Overclockers UK and picked one up. The PM961 and SM961 are the precursors to the 960 Pro (see p20) –

Samsung's replacement for the superb 950 Pro.

The latter already offers some incredible speeds, but the new models can reportedly top 3,000MB/sec and 1TB models are available too, whereas the 950 Pro only came in capacities up to 512GB.

Unfortunately, my wallet is still reeling from the purchase, and I may need to live off beans and

toast for a month, but a quick run through CrystalDiskMark with my shiny new 1TB PM961 revealed some mind-boggling speeds that helped to lift my spirits.

The read speed was over 3,400MB/sec and the write speed was a spectacular 1,634MB/sec – much faster than Samsung's quoted figures. I doubt I'm the only person who is excited by these new SSDs, and having 1TB of ultra-fast storage makes me feel like I won't have to upgrade my SSD for quite a while. Prices will likely come down too – I expect they'll eventually cost under £300 inc VAT.

However, an interesting idea hit me when I realised I could have 1TB of storage space in my modded mini PC without a 2.5in or 3.5in bay. What will these SSDs mean for case manufacturers and modders? There's



now a real need for cases to cater for the fact that 3.5in and 2.5in drives aren't needed by everyone anymore. This theory doesn't just apply to mini-ITX systems, although there are perhaps more obvious benefits to smaller systems as they have more of a space premium.

You don't have to spend upwards of £300 on a 4x PCI-E NVMe M.2 SSD either – there are plenty of 1TB M.2 SATA-based SSDs available that cost less than £240, with prices continuing to fall. In the absence of any real competition, other than U.2 drives, which remain expensive, M.2 is here to stay. The fact that the socket sits on the motherboard itself in a majority of situations could provide an opportunity for case manufacturers to start redesigning their products, and for modders to start creating cases where drive mounts simply aren't needed, meaning they can better use the space.

Combine this change with the growing popularity of SFX PSUs – a form factor that Thermaltake has embraced with its new Core G3 – one of the first ATX tower cases to have an SFX PSU mount to reduce the case width considerably, and the next year or two could see some big changes in case design.

Hands on with Alphacool's Eiswand external cooling system

Alphacool offers a huge range of products in practically all areas of water cooling, although many of its offerings are designed more to be

functional rather than pretty, especially compared with some of the shiny kit available from the likes of EKWB and Bitspower. That said, I nearly always use Alphacool's radiators, simply because they come in all different shapes and sizes and are very good value for money. This month, though, Alphacool sent me a prototype of a very different product that might boost the company's aesthetic credentials – the Eiswand.

It's an external cooling system, complete with pumps, a 45mm-thick triple 120mm fan radiator with two rows of fans in push/pull mode, a reservoir mounted at the top with a fill port and an illuminated base. It looks stunning and it feels very



The Eiswand feels very solid, being made from steel, and it has a decent finish too

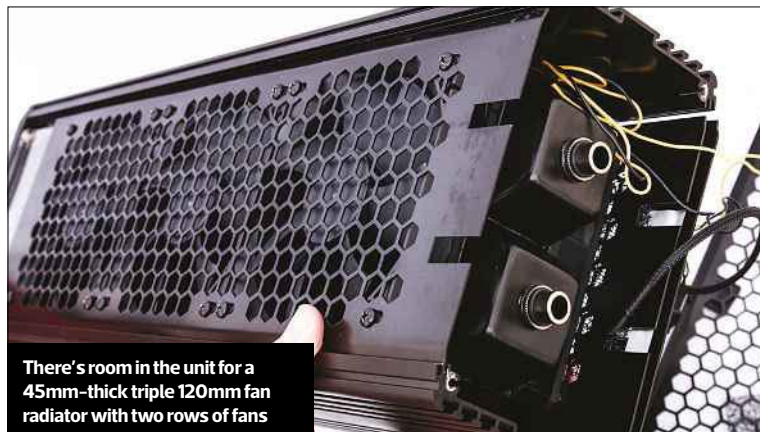
solid too, being made from steel, and it has a decent finish too. The kit includes all the gear you need to water-cool your PC, including a CPU waterblock, coolant, tubing, fittings and an external mains-powered adaptor for the radiator unit.

It includes a pair of quick-release fittings too, so you can quickly detach the radiator section from your system if you need to move it. There are two G1/4in threads in the base of the radiator unit, which act as an inlet and outlet, while two of Alphacool's mini DC-LT pumps sit in the base. The shell slots together, but it's possible to dismantle it in order to get at dust filters and expose the fans. This size of radiator should be able to deal with any CPU and single graphics card, and the fill port is very accessible and the kit includes everything you need.

Being in prototype stage, there are one or two omissions – Alphacool will be replacing the fans with quieter ones, and there's currently no way to control the speed of the fans. There's no word on price yet, but Alphacool says it will rectify the fan situation soon. When the unit is available in retail form, I'll be testing it to see how it fares as an external cooling system. **GPG**



The two G1/4in threads in the base of the radiator unit act as an inlet and outlet



There's room in the unit for a 45mm-thick triple 120mm fan radiator with two rows of fans



Two of Alphacool's mini DC-LT pumps sit in the base

How to

Mix your own coolant colours

Want to colour-match your coolant to the rest of the system, but can't find quite right the colour? Antony Leather looks at how to mix your own coolant cocktail

 **TOTAL PROJECT TIME** / 1 HOUR

There are a number of coolant manufacturers now, although UK-based Mayhems (<https://mayhems.co.uk>) is the best known, offering a huge range of colours in transparent, opaque and pastel flavours, as well as fancy effects, such as its pearlescent Aurora 2 coolant. It also offers a range of dyes, which makes it practical to match off-the-shelf coolants with your hardware and case.

This month, we're going to look at using Mayhems' base coolants, colours and dyes to create your very own tailor-made coolant. Want an Aurora 2 effect, but in a colour Mayhems doesn't offer? Want a pastel red colour but Mayhems Pastel Red isn't quite the right shade? We'll not only cover how to make your own colours, but also how to create your own custom Pastel and Aurora 2 coolant mixes to match your system's colour scheme.

Before you start

Mayhems dyes are now usually non-staining, but some objects can still absorb them, so it's always best to create a safe workspace where spills won't do any harm, covering any carpets or clothes. You'll then need to build your water-cooling system into the case as completely

as possible **1**. If you leak-test it outside the case, then dismantle it and install it, the entire loop will effectively be untested.

You'll also need a few bits and pieces. You'll want a measuring jug **2**, and we recommend using a clear glass to gauge the colour of the coolant **3**, giving you a better view and easier access than a reservoir.





It's best to use a cheap disposable glass, as it may end up getting stained, depending on which dyes you're using. Finally, you'll need plenty of transparent base liquid before you start adding dyes – either deionised water or Mayhems clear coolant will be fine [4](#).

Creating basic coolant

To simply create a Mayhems dye-coloured coolant, add a maximum of half a bottle of dye to one litre of transparent coolant. Add a few drops of dye at a time [6](#); adding too much dye can lead to a darker colour than you want. You can use more dye to create a darker, more vivid colour [6](#). For a lighter shade, simply add more clear coolant. You can also add colours to make tints, which we'll discuss later.

Mixing two colours

If you want to mix colours to create a custom transparent coolant, simply choose two dyes and add equal amounts of them to your clear

coolant base. Start by adding one colour and stirring the coolant [7](#). You can then add the second dye a drop or two at a time, stirring each time until you get to the colour you want.

Here, we've added blue and emerald green to create a deep turquoise colour [8](#).

You can continue to add a drop at a time from both dye bottles to fine-tune your colour [9](#), but remember not to use more than half a bottle in total in each litre of transparent coolant.

Darkening and lightening

To create very dark colours, you can add Mayhems Black X1 concentrate to an existing colour. You only need a few drops, so consider buying a pipette so you can add small amounts, and practise first with a small amount of coolant.

Here, we've made a blood red colour using normal red dye with a few drops of Mayhems Black X1 concentrate [10](#). If you want to lighten



the mixture, or start with a lighter shade at the beginning, add more clear coolant, which will dilute the dyes [11](#).

Black transparent coolant

Mayhems offers black dye in the form of its X1 transparent concentrate [12](#), so it's possible to create black coolant, which we used in the darkening and lightening section. This 250ml container of concentrate can create two litres of coolant when added to 1.75 litres of clear coolant, such as deionised water.

Colour matching

Half the fun of creating your own coolant is being able to colour-match it to your case or components. In our example, we'll combine three colours to match the orange/red heatsinks on a motherboard [13](#). Our

motherboard's heatsinks are mainly red, but there are also hints of pink and orange in the colour.

Again, it's best to start with a small amount of coolant and then work out how much you need to add. We created a light red base using red dye first [14](#). We then added our orange dye a drop at a time until we got closer to the target colour, and then added two drops of pink. Place your mix next to your hardware to see how close you're getting [15](#).

Pastel colours

Pastel coolants have solid, vivid and opaque colours. If you want to create your own pastel coolant, you can use a 250ml container of concentrate and add it to 750ml of clear coolant, creating one litre in total. Note that pastel concentrates make up less coolant in total than



transparent concentrates. Mayhems also sells pre-mixed pastel colours such, as this pink one [16](#).

To create a pastel colour using concentrate, such as our orange example, simply pour the concentrate into a container and then add the correct amount of clear coolant or deionised water [17](#).

You can also create custom pastel colours by using a white pastel base and adding dye, or by combining pastel concentrates to create your own colour. The latter is simple, and it's achieved in the same way as mixing the dyes earlier in this guide. For our example, we've created a turquoise pastel colour by combining blue, UV green and black pastel concentrates [18](#). A cheaper and more flexible way to make a custom pastel coolant is to add dyes to a white pastel base liquid [19](#). You can buy a white pastel base liquid ready-made, or you can create one yourself using white concentrate and deionised water.

If you need a lighter colour of the pastel shade you've created, you can simply add a little more white pastel base liquid to tone it down [20](#). Add a splash of it to your coolant until it reaches the right colour. Conversely, if you want a darker shade, you can add black X1 concentrate or black pastel coolant to your mix [21](#). You'll only need a few drops of the former or a splash of the latter to create a less vibrant, darker colour.

Aurora effects

Mayhems' best-looking coolants are found in its Aurora range, featuring pearlescent particles that move around in the coolant and look great in reservoirs [23](#). The downside is that you could only use them for short periods, as the pearlescent particles eventually 'fall out' of the coolant and end up getting trapped in your water-cooling



components. If you're planning to photograph your Aurora loop, then do it soon after you've built it. You should also avoid using Aurora coolant in complicated loops, or in systems with drain ports, as the particles can collect in them.

Aurora comes in three guises. Firstly, there's the ready-mixed version, which you can add directly to your system. If you just want simple red or blue Aurora colours, then these ready-mixed versions are your best options, and they can be bought in the usual one-litre containers [24](#).

Alternatively, there are concentrates and additives. The concentrates require the addition of 750ml of clear coolant, just like the X1 transparent concentrates. In our example, we've added red concentrate to Mayhems Ultra Pure coolant [25](#). There are also boosters, which can enhance the silvery effect or add gold effects.

There are only a few colours of Aurora from which to choose, so you may well want to create your own colour. Start with a coloured Aurora coolant as a base, such as our red example. Then add any dye or X1 concentrate to the mix to create your own colour. Here, we've added yellow dye to create an orange colour instead [26](#).

As we mentioned earlier, though, Aurora and Aurora 2's pearlescent particles can potentially stick to your components and tubing if they're used for too long, so the coolant needs to be thoroughly flushed out of the loop once you've finished showcasing your PC. You should use a high-power pump and flush deionised water thoroughly through each component.



UV effects

Ultraviolet effects [27](#) can be created in two ways. Firstly, there are dyes for creating UV-reactive transparent coolant, which you can add in the same way as the dyes we covered earlier in the guide.

Mayhems also offers UV versions of its pastel coolants in both ready-mixed and concentrate form. You can simply use these coolants in the same way you'd use the normal versions [28](#), with the 250ml concentrate version needing to be mixed with 750ml of clear coolant to create one litre. **GPC**

Folding@Home

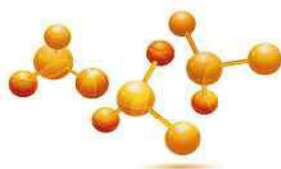
Join our folding team and help medical research

MILESTONES THIS MONTH

USERNAME	POINTS MILESTONE	USERNAME	POINTS MILESTONE	USERNAME	POINTS MILESTONE	USERNAME	POINTS MILESTONE
Dicksoutforharambe	20000	Krisad	700000	mort6dav3	6000000	Bloo_Toon	40000000
eddiebiggs	30000	mar_duke	800000	RDL_Mobile	8000000	pompeyrodney	60000000
oli123456789	40000	anadir	1000000	jonesd98	9000000	Little_Willie	70000000
Matt_Livemore	70000	AnonymouUnicorns	1000000	wew	9000000	Portchylad	80000000
Oldfield12	80000	john251282	1000000	Anonymous	10000000	Trunkey	90000000
BP_Evil_Element	400000	Nex79	1000000	elspuddy	10000000	SirBenjaminNunn	100000000
OrigamiMasters	600000	MikePreston	3000000	PCEnthusiastUK	10000000	Unicorn	200000000
trma97	600000	NFGCS	4000000	kcanti	20000000	daxchaos	300000000
dumbdodo	700000	FurstyFerret	5000000	Acanuck	40000000	PC_Rich	900000000
GarethFlatlands	700000	Lunnbow	5000000	adbygrave	40000000		

WHAT IS FOLDING?

Folding@home uses the spare processing cycles from your PC's CPU and graphics cards for medical research. You can download the client from <http://folding.stanford.edu> and our team's ID is 35947. Once you pass a significant milestone, you'll get your name in the mag. You can also discuss folding with us and other readers online at the www.bit-tech.net forums.

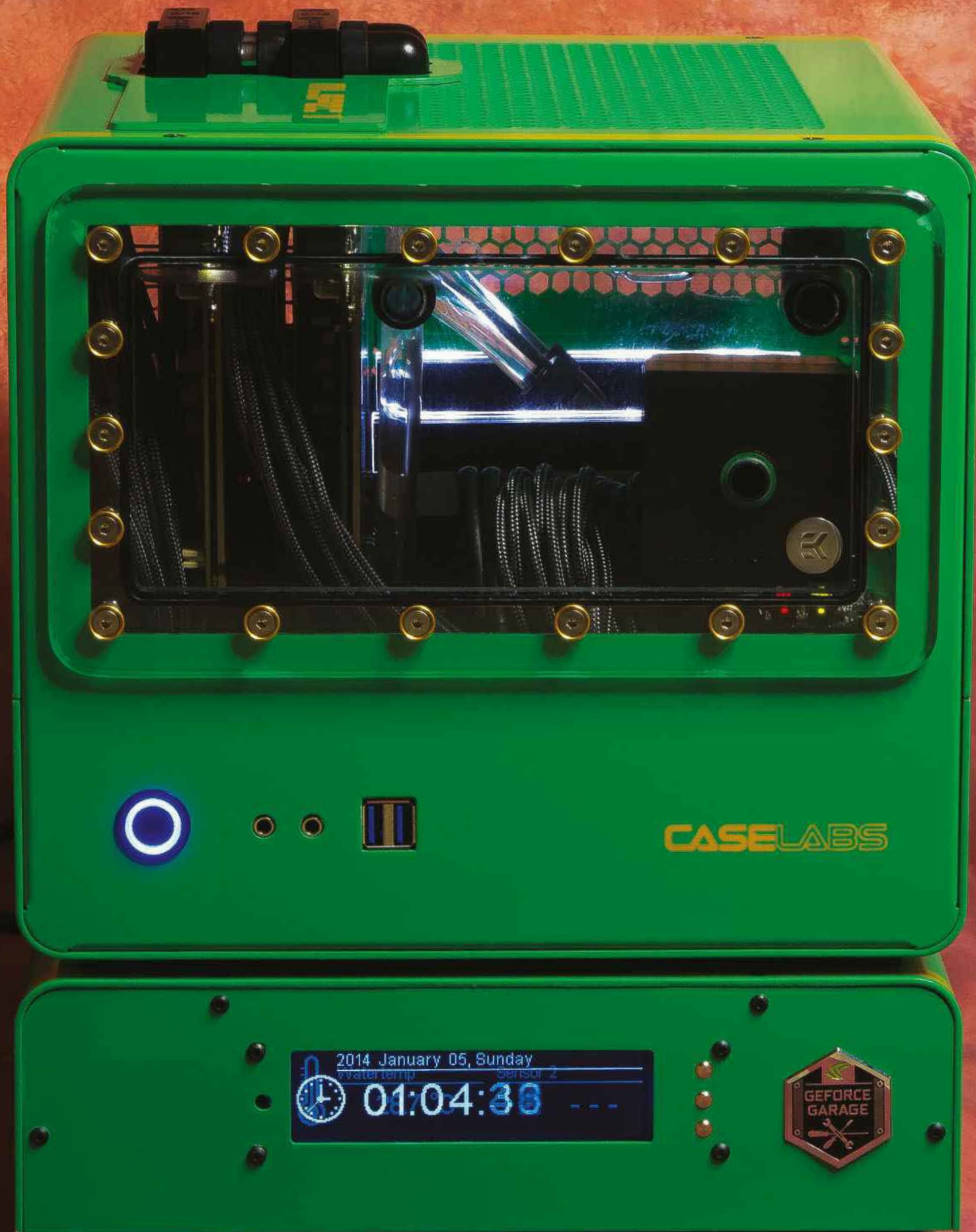


TOP 20 OVERALL

RANK	USERNAME	POINTS	WORK UNITS
1	DocJonz	2,904,204,537	209,517
2	Nelio	2,758,803,159	259,098
3	HHComputers	2,433,087,289	64,394
4	piers_newbold	1,181,789,037	66,874
5	Scorpuk	1,078,059,420	37,962
6	coolamasta	951,063,112	187,345
7	PC_Rich	912,386,065	92,830
8	Lordsoth	877,207,124	110,524
9	Slavcho	577,265,615	40,148
10	Laguna2012	574,350,738	30,842
11	StreetSam	571,113,589	90,251
12	johnim	534,006,305	83,261
13	Dave_Goodchild	471,560,487	121,853
14	Desertbaker	456,369,828	26,874
15	The_M2B	456,056,211	68,147
16	apeman556	446,094,942	33,942
17	KevinWright	390,091,940	35,504
18	daxchaos	307,163,435	9,975
19	Dickie	297,554,077	28,401
20	Roveel	281,313,186	6,858

TOP 20 PRODUCERS

RANK	USERNAME	DAILY POINTS AVERAGE	OVERALL SCORE
1	HHComputers	6,264,453	2,433,087,289
2	DocJonz	5,347,419	2,904,204,537
3	PC_Rich	3,319,139	912,386,065
4	Lordsoth	2,123,133	877,207,124
5	piers_newbold	1,990,329	1,181,789,037
6	Nelio	1,558,487	2,758,803,159
7	Trunkey	1,275,423	91,616,383
8	madmatt1980	1,204,636	242,058,053
9	apeman556	1,132,620	446,094,942
10	Roveel	1,095,671	281,313,186
11	Unicorn	1,069,647	215,504,138
12	Desertbaker	784,485	456,369,828
13	Slavcho	713,744	577,265,615
14	elspuddy	673,212	17,552,776
15	Laguna2012	578,762	574,350,738
16	BeezaBob	500,426	235,821,328
17	daxchaos	412,719	307,163,435
18	SirBenjaminNunn	393,949	108,480,693
19	TheFlipside	390,010	274,648,467
20	The_M2B	379,753	456,056,211



Readers' Drives

Mil-Spec II

After spotting CaseLabs' BH4 air-cooling chassis on a forum, Daniel Harper rose to the challenge of packing a water-cooled, 6-core SLI rig into this small case

GPG: What was the original inspiration behind this project?

Daniel: I saw a discussion about CaseLabs' BH4 case on the OCN CaseLabs subforum. I was drawn to its compact size and the fact that it was aimed at air coolers instead of the CaseLabs water-cooling faithful – the fact that it was going to be a real challenge only sweetened the deal.

GPG: How did you find the CaseLabs chassis – is it modding and water-cooling friendly?

Daniel: It's a good chassis for modders that stretch themselves, but it's not water-cooling friendly out of the box – an all-in-one liquid cooler is probably its limit, but then water cooling was never CaseLabs' design goal for this case. Another good reason to use this case is because Jim at CaseLabs is very

accommodating when it comes to supplying with me spare panels or 'blanks' – if I botch a piece with one of these cases, it's easy to get a replacement part!

GPG: What specs did you choose and why?

Daniel: I wanted to use this PC for CAD/CAM and all-round POWAAAAAAAAH! I built it around what I think were the best components at the time for me, such as the Asus WS motherboard and the two GTX 980 Ti graphics cards – the WS board had enthralled me for ages, so I had to use it.

GPG: What other mods have you built?

Daniel: I've built quite a few now, and all of them brought me joy during their construction. I learn a little more with each one.

GPG: What difficulties did you come across?

Daniel: Space, or rather the lack of it! Every component had to be slimmed down to make it fit, so the radiators are the skinniest ones you can buy, the reservoir is only 20mm thick and so on – it all helps when you're trying to squeeze as much as possible into a small case. It didn't lose any storage capabilities though – there's an SSD and a hard drive in the case. I could have put radiators in the main chassis, but I wanted to keep the open look that the front reservoir would bring, so I used a radiator pedestal instead, using the lower case shell as a base for continuity.

Power was also a concern with my plan to run two graphics cards in SLI configuration – the BH4 is built to house SFX PSUs, and no SFX PSU is going to drive a pair of GeForce GTX 980 Ti cards and an overclocked 6-core CPU, so I fitted two SFX PSUs instead – a 600W unit for the CPU and one graphics card, and a 450W unit for the second card and ancillaries – both PSUs are made by Corsair. Another concern was the sheer size of the Asus Strix graphics cards – they're massive! I had to chop a hole in the case just to get them inside with the waterblocks on them. That hole made a nice design feature, though, along with the SLI bridge poking through it.

GPG: Why did you use rigid tubing and did this decision present any issues?

Daniel: Because rigid is what I do – I haven't used floppy tubing for years now. I mean, why would you? Tubing that goes ranky every other month



/MEET THY MAKER

Name Daniel Harper

Age 41

Location London

Occupation Niko's minion at EK now!

Main uses for PC All the things

Likes Slovenia, In Win and single flute bits

Dislikes Food with a face, humidity and poorly made cases with no style



vs tubing that stays clear forever – it's a no-brainer for me.

CPC: What tools and/or machinery did you use?

Daniel: I recently invested in a Shapeoko 3, so the range of materials with which I can work has shot up, along with the overall quality of work – everything in this project was made 'in-house' – it's nice not to have to rely on others in order to see your design unfold. I also splashed out on an SRI Pro Lite spray gun, which is amazing, while the sidekicks of Solidworks/HSMworks took care of the design and CAM side of things. I also got

the airbrush out again for the detail, although that was a demanding job – I'll be doing a lot more airbrushing, as I need the practice!

CPC: How long did the build process take?

Daniel: This project had a very fast turnaround, as I was at home recovering from DVT, following a long-haul flight from Taiwan after the Mod in Taiwan competition. The build was turned around in about two months – lightning fast for me!

CPC: What did you learn from the build process?

Daniel: Small is awesome!

CPC: Are you happy with the end result, and is there anything you'd do differently if you built this project again?

Daniel: I would add chromed tubing and a slightly larger lower clamshell so I could use larger radiators. The cooling is acceptable – the 12°C load delta T when gaming is perfectly okay, but I would like some more overhead, to be honest. The KLEVV RAM and the WS board go together like stickle bricks, though, as if they were made for each other, so I wouldn't change that. And the green; I would probably go for a much lighter, pastel tone now. Next time, eh? **CPC**

BE A WINNER

To enter your machine for possible inclusion in Readers' Drives, your mod needs to be fully working and, ideally, finished based in the UK. Simply log on to www.bit-tech.net and head over to the forums. Once you're there, post a write-up of your mod, along with some pics, in the Project Logs forum. Make sure you read the relevant rules and advice sticky threads before you post. The best entrant each month will be featured here, where we'll print your photos of your project and also interview you about the build process. Fame isn't the only prize; you'll also get your hands on a fabulous selection of prizes – see the opposite page for details.

SYSTEM SPECS

CPU Intel Core i7-5820K overclocked to 4.3GHz

Graphics card 2 x Asus Strix GeForce GTX 980 Ti

Case CaseLabs BH4

Memory 16GB KLEVV Cras DDR4

Motherboard Asus X99-M WS

Storage 1TB SSD, 3TB hard drive

PSU 450W Corsair SFX and 600W Corsair SFX

Cooling Custom loop made with EK components – EK magnificence all over me!

THANKS FROM DANIEL: Many thanks to the teams at CaseLabs, Asus UK, KLEVV memory, my hombres at EKWB and Tom Logan for giving me the WS board that I'd been lusting over for a long time! Also, congratulations to Kevin at CaseLabs for the birth of little Lilly!

Win all these prizes!

We've teamed up with some of the world's leading PC manufacturers and retailers to offer this great range of prizes to each lucky Readers' Drives winner. If your creation is featured in the magazine then you'll walk away with all of the prizes listed on this page, so get in your entries!

Corsair graphite Series 230T case and RM 550w Modular power supply

TOTAL VALUE £150 inc VAT / **MANUFACTURER** www.corsair.com

Corsair believes that a great PC starts with a great case. The Corsair Graphite Series 230T is a compact expression of this core philosophy. With stylish looks and a choice of three different colours, it packs in a remarkable number of features to provide builders with tonnes of room for expansion and amazing cooling potential. Like all Corsair cases, it's built using the finest materials and finished to the highest standards, so it will withstand several years of upgrades. Plus, to make sure it stand out from the crowd, the 230T features Corsair's new Air Series LED high-airflow fans, providing distinctive lighting with low-noise, high-airflow cooling.

Just as a quality case is essential to building a quality PC, a high-performance, a high-quality power supply is also a vital ingredient. The all new RM series has been built from the ground-up to deliver unmatched reliability alongside 80Plus Gold efficiency, and all with the absolute minimum of noise. It uses specially optimised quality parts to reduce sound at the component level, and it's completely silent below 40 per cent load, thanks to its Zero RPM fan mode. It's also fully modular, allowing for the maximum amount of flexibility during installation. With a Corsair Graphite 230T case and an RM 550W Modular power supply at the heart of your build, you'll have the foundations for a truly awesome gaming machine.



Mayhems coolant and dyes

VALUE £50 inc VAT /

MANUFACTURER www.mayhems.co.uk



Cooling performance is only one part of the equation when it comes to kitting out your rig with custom water-cooling gear. The other major bonus is that all those tubes and gleaming fittings just make your PC look damn sexy, and they look even better when they're pumped full of fancy coloured coolant. As such, we're particularly pleased to have the folks at Mayhems now on board with Readers' Drives; they're currently offering two 1-litre bottles of Mayhems' Pastel Ice White coolant, along with a selection of five dyes, so you can choose the colour that best complements your PC. Check out the blue coolant in our own mini PC mod on the cover of Issue 109 for an example of what's possible with some Mayhems coloured coolant.

Phobya Modding Kit

VALUE £50 inc VAT **MANUFACTURER** www.phobya.com, www.aqua-tuning.co.uk

The Phobya modding kit is designed with the modder in mind, offering great value for money and quality products. The kit includes Nano-G 12 Silent Waterproof 1,500rpm multi-option fans, which use an innovative fan-blade design. As standard, the fans include braided black cables to keep your case looking as neat as possible. The fans are also supplied with a special cable that lets you run the fan at 5V rather than 12V, reducing the noise emitted in order to help you to build a silent system.

The kit also includes the 60cm Phobya 3-pin Molex to 4x 3-pin Molex Y-cable. This pre-

braided extension cable gives you extra routing options in your case, and it also enables you to run up to four fans from one compatible

motherboard header. Meanwhile, the Phobya SATA 3 cables included in the kit offer the same great quality braiding as the rest of the Phobya range, while also securing your connection with latched connectors.

As well as this, the kit includes the Phobya SlimGuide Controller, which gives you the option to vary the speed of other fans in your case, while the Phobya TwinLEDs let you shine a light on your mods.





JAMES GORBOLD / HARDWARE ACCELERATED

IT'S TIME FOR ATX TO RETIRE

But there's also a shortage of innovative cases, argues James Gorbold

Two of my many responsibilities at Scan are deciding on the spec of our 3XS PCs for our website and designing systems for customers with a specific set of requirements. Again and again, I'm struck with the fact that, for all the PC has changed in the past few decades, ATX is still by far the most popular form factor.

First launched more than 20 years ago by Intel, ATX is only the second form factor in the entire history of the PC to be popular enough to become the de facto standard. There have been attempts to replace ATX, such as BTX over ten years ago, but it was soon scrapped when more power-efficient CPUs emerged. But I think ATX is long overdue for retirement, not because it can't cope with the thermal or power requirements of modern components, but simply because it's unnecessarily large.

I say unnecessarily large, because the only real advantage of ATX over smaller form factors is expandability, with support for up to seven expansion slots, which is a frankly ludicrous number for most PCs. How many times in the past 15 years have you only installed a graphics card in your ATX board, leaving most of the slots free and over 50 per cent of your case's interior volume empty? Motherboards have so many SATA ports that you no longer need to add extra drive ports or a costly RAID controller, while USB has dispensed with the myriad cards required to connect a printer, scanner or proprietary external storage device. Meanwhile, the improved quality of on-board audio and networking has done away with the need for dedicated sound cards and network cards for most people.

In most cases, ATX PCs really are too big for their actual use, with a huge amount of wasted space. For me, mini-ITX goes a

step too far with the shrink ray, as there's no option for a second graphics card, or a decent sound card if you need one. In addition, if you place a mini-ITX case under your desk, it becomes awkward to use the buttons and USB ports, as they sit just out of your reach.

Instead, I think micro-ATX is the ideal form factor for a PC, as it strikes the perfect balance between upgradability and size. For instance, with support for up to four expansion slots, you could easily slot in several cards and still have a PC that's considerably smaller than an ATX rig.

In the past, you had to make significant compromises if you wanted to build a micro-ATX PC. For instance, micro-ATX (and mini-ITX) boards used to be woeful for overclocking, but these days they're just as good as full-sized ATX boards. These previous compromises belong to a legacy of big OEMs seeing micro-ATX as a budget platform, so motherboard manufacturers simply didn't

make high-end micro ATX boards. That's no longer the case now, with a full range of chipsets available on micro-ATX boards, including Intel's top-end X99 chipset.

What's really holding back micro-ATX from taking over from ATX, though, is that most compatible cases look like throwbacks to the year 2000, with dull, uninspired designs. I quite like the Corsair Obsidian 350D, but even that case looks a little old-fashioned with its two 5.25in drive bays.

Surely I'm not alone in thinking that it's silly to continue making half-empty PCs when a perfectly good, and more cost-effective, alternative has already been designed. It just needs a few more decent cases to put a viable enthusiast PC micro-ATX marketplace together. **GPG**

How many times in the past 15 years have you only installed a graphics card in your ATX board?

James Gorbold has been building, tweaking and overclocking PCs ever since the 1980s. He now helps Scan Computers to develop new systems.



LAPDOG

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